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EARTH AND SKY

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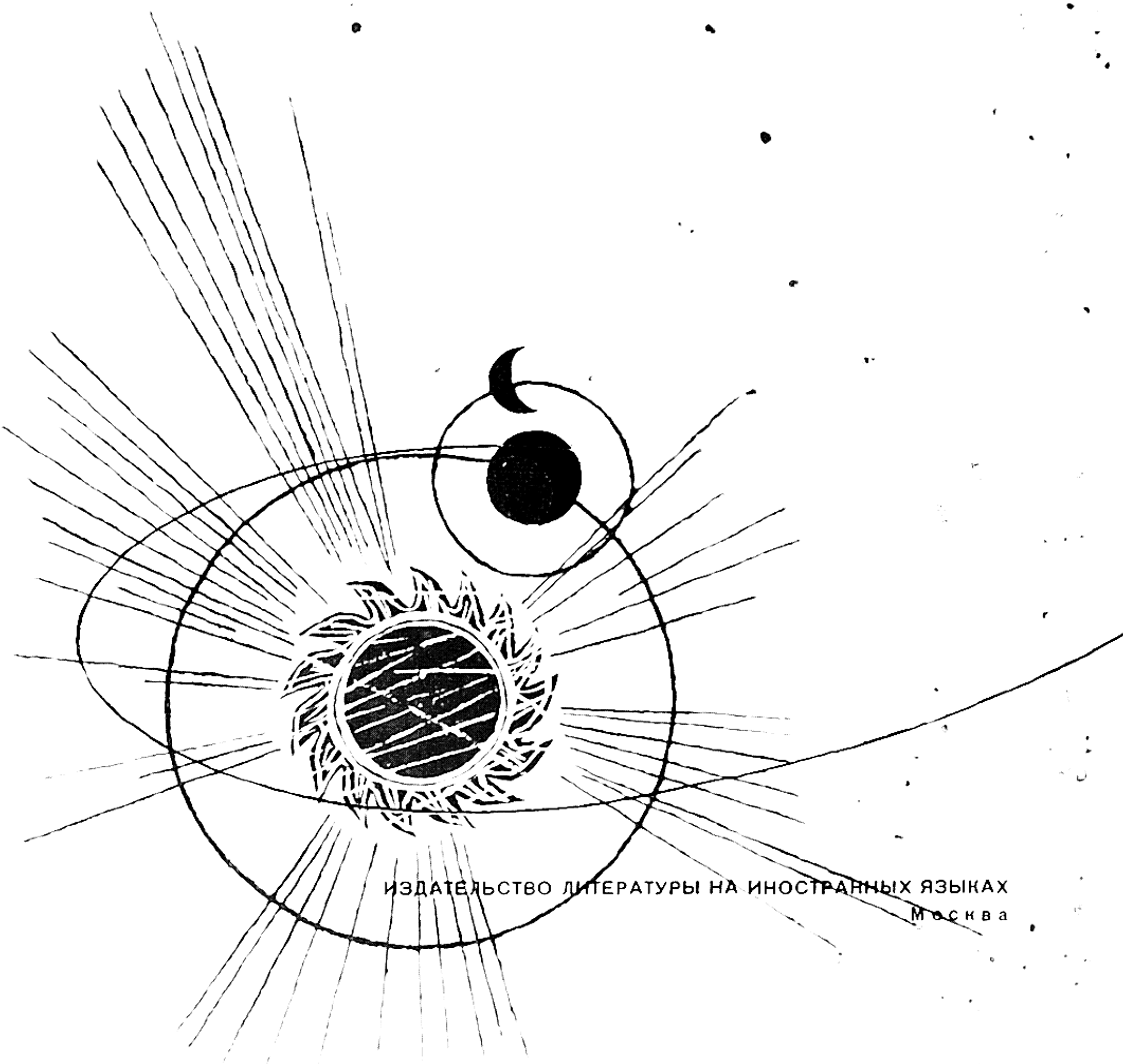

ИЗДАТЕЛЬСТВО ЛИТЕРАТУРЫ НА ИНОСТРАННЫХ ЯЗЫКАХ
Москва

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PART THREE

INTRODUCTION

When you are out in the open country at the time of a full Moon, take a good look at the night sky.

The Moon's soft, silvery light floods the Earth but it is much weaker than sunlight and although things close at hand are visible distant objects are obscured by a blue haze.

The sky, too, is lit up by the Moon; stars close to it are lost in its brilliance and even those more distant are paler than they would be on a moonless night.

In clear weather the night sky is one of the grandest sights in nature—the bright face of the Moon and the thousands of twinkling stars scattered over the dark sky provide a picture that one can admire for hours on end.

And then the Moon begins to sink towards the horizon, finally disappearing completely; the sky darkens, more and more stars appear and all of them seem to grow brighter.

The best time to study the sky is on a warm summer night, sitting on a river bank with a fishing-rod or lying on a lonely hilltop in the open steppe. The short night passes quickly, the red glow of dawn appears in the east. One after another the stars disappear from the sky. Only the very brightest remain until, at last, they too have gone.

Far away in the east the edge of the Sun rises above the horizon, its dazzling brilliance marking the beginning of a new day.

From the very earliest times man has asked himself countless questions as he gazed at the sky.

What is that huge bowl overhead? Is it made of something hard, like transparent crystal? Has it got a rim that rests on the Earth? What are those countless twinkling stars? Are they as small as they seem to be? Are they fixed to that heavenly bowl or do they move freely in space?

Why does the Moon move about among the stars? Why does it change its shape; why is it sometimes a disc, sometimes like a narrow sickle and sometimes not there at all?

Why does the Sun rise high overhead in summer and warm the Earth, but on frosty winter days does not rise far above the horizon and is in a hurry to hide its face again as though unwilling to look at the snow-covered fields and ice-bound rivers?

Astronomy, the study of the stars, goes back to very ancient days; it is a Greek word coined from *astron*, a star, and *nomos*, a law.

You may wonder why our ancestors should have wanted to study the sky and discover the laws governing the movements of heavenly bodies. What use could it have been to them?

Such a study was not only useful, it was indispensable. Long, long ago people began to till the Earth and keep herds of cattle. The herdsman and the farmer had to know when spring would come, when it would be followed by summer and after summer when the rainy autumn would begin. And so man began to watch the Sun: when it rose higher in the sky and its warmth could be felt, that meant the end of winter and the beginning of bright, warm spring days.

The people of ancient Egypt, China and India had very good reasons to study the Sun's movements. There are huge rivers in those countries, and when they overflow their banks they cover the fields with fertile soil called silt. And the people who lived in the river valleys had to know exactly when the floods would begin, not only because they had to prepare their seed for planting but also because they had to make sure that their goods and chattels and even their own lives were safe from the huge waves carried by the swollen rivers.

Such a study could not be made by the ordinary people, the herdsmen and tillers of the soil; it was done by the priests who served the temples.

The priests, therefore, were the first astronomers. By studying the movements of the heavenly bodies they were able to forecast not only the time the floods would begin but were also able to say when there would be eclipses of the Sun and the Moon. This knowledge of astronomy gave the priests great power over the people, so great that even kings obeyed them.

In addition to the herdsmen and farmers, those who sailed the sea or travelled long distances by land also studied the heavenly bodies; the Sun showed them their way by day and the stars by night.

Astronomy helped the people of antiquity to make the first maps of the ancient world. Even today the ability to draw maps correctly depends on a knowledge of astronomy.

As you see, the "heavenly science" is closely bound up with the needs of the people.

PART ONE

WHAT SHAPE IS THE EARTH?

Every schoolboy knows that the Earth is round, that it is shaped like a ball and moves through space.

A long time ago people believed that the Earth was a flat disc or was a little bit convex (like an ancient warrior's shield) and that it rested on some support. Different peoples had different ideas concerning these supports on which the Earth stood.

The people of ancient India believed that the Earth was a hemisphere held up by four elephants and that the elephants stood on a huge tortoise. They did not seem to have worried about asking what the tortoise stood on.

In the old days in Russia a little boy, thirsting for knowledge, would ask:

"Grandad, what holds the Earth up?"

"Whales, my boy, great big whales," his grandfather would answer. "And when the whales wag their tails we get earthquakes."

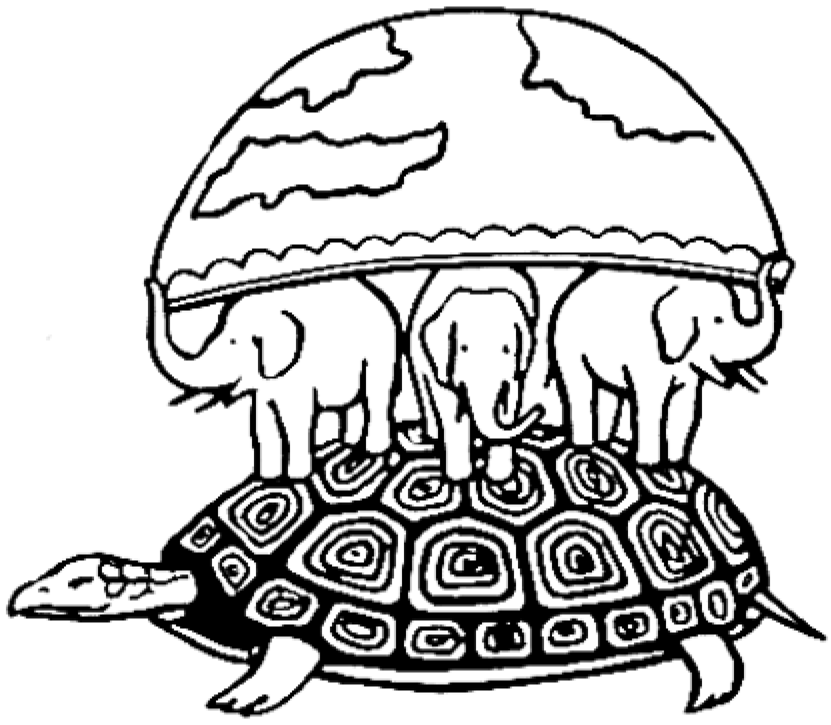
"And what are the whales on, Grandad?"

"They're in the water, my boy."

"And where's the water, Grandad?"

"On the Earth, my boy."

"And what is the Earth on?"



"Aren't you the stupidest child! Haven't I told you, the Earth stands on the backs of three whales!. . ."

Such an argument could go on without end.

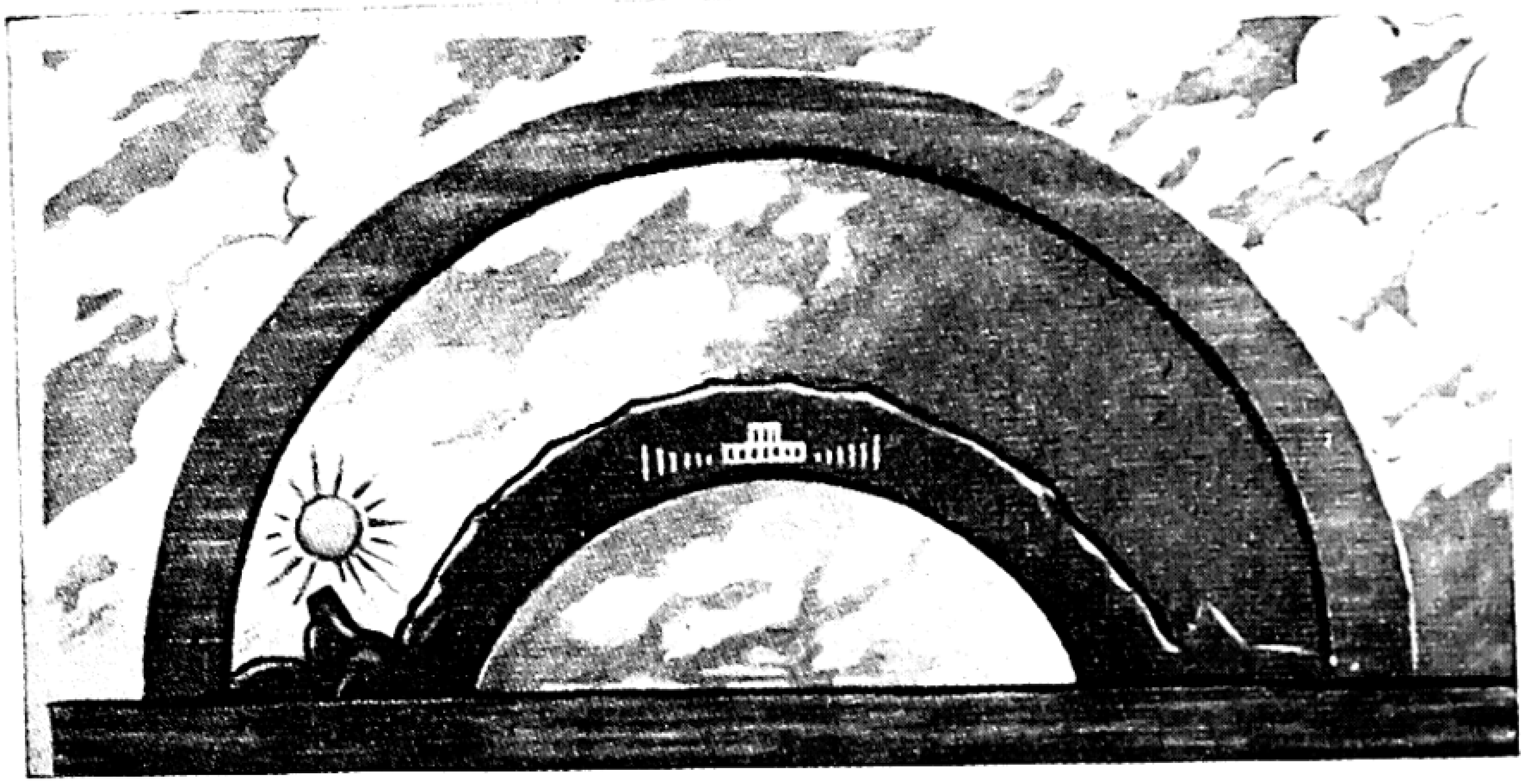
It is not surprising that for a long time people thought the Earth was as flat as a table top; the surprising thing is that man's intellect enabled him to discover the true shape of our planet. Of course, it took thousands and thousands of years and it became easier to understand when men began to make long journeys by land and sea.

People began to travel about the Earth so long ago that no historian can tell us when the first journeys were made. People were forced to move from place to place on account of forest fires, floods, hunger, the ice that came down from the north, the sands that spread from the deserts. . . .

Primitive man made his journeys very slowly, that is why it is more correct to speak of migration rather than travel. Nevertheless, in the course of migrations lasting many years, people travelled thousands of kilometres.

Later in history men went to other places to barter; hunters exchanged the skins of animals for swords and knives and for strong metal vessels; the tillers of the soil exchanged grain for cloth and for pretty bracelets and necklaces. It stands to reason that such barter could not be carried out by whole tribes; there were special people who went from country to country to trade—the merchants.

These merchants of olden days were enterprising and brave men: they had to fight against nature and to defend themselves from wild beasts; they also had to fight



The Earth as the Babylonians imagined it

against enemies who attacked them to rob them of their goods.

Merchants made many long journeys both on land and on tiny ships across the seas.

About 700 years ago the Italian merchant Marco Polo travelled all the way from the city of Venice in Italy to China. He journeyed overland, crossing high mountains and wide deserts, and returned by sea, along the coasts of South Asia.

Marco Polo left his native city as a youth and returned in middle age. He was away from home twenty-four years, lived seventeen years in China and spent seven years on the road there and back.

After his return to Venice, Marco Polo lived for a long time and wrote a big book about how people lived in China in those days.

Two hundred years later a Russian merchant, Afanasy Nikitin of Tver, made a journey to the East. Nikitin travelled from North Russia, through Persia to distant India and described his journey in an interesting book called *A Journey Beyond Three Seas*. Nikitin's journey to India took him six years.

In those old days it took people a long time to get from place to place. Journeys that take a week or two today took them many

years; they had no fast airliners, or even railways and steamships to travel by. On land the merchants travelled with caravans of horses and camels and on sea in tiny sailing ships.

Nevertheless, many people undertook long journeys in those days. The memory of their travels was soon lost, for not many people could write books like Marco Polo and Afanasy Nikitin to tell of their adventures.

These journeys to distant parts helped people get a fuller and better understanding of the world. Maps of the Earth's surface appeared, although for a long time they were inaccurate and far from complete.

Look at the map on the opposite page, drawn by a geographer more than two thousand years ago. The Earth is shown as a flat disc, like a dinner plate, and the dry land is surrounded by the River Oceanus. In the middle of the dry land there is a big sea that people even in times of antiquity knew very well: this sea was crossed by merchants, warships and pirates. The sea was called the Mediterranean, from the Latin words *media*, middle, and *terra*, land, because people thought it was in the middle of the world. Everybody now knows that this is not true but the name has remained.

On our maps today we see a network of lines, the lines of latitude and longitude; these lines help us fix the position of any point on the globe.

This network, marked in degrees, was invented more than eighteen hundred years ago. An ancient Greek astronomer, Ptolemy, collected all the available geographical information and compiled a map of the Earth such as the Greeks and their neighbours believed it to be.

The map included the whole of Europe (except the northern parts), North Africa and a considerable part of Asia.

Ptolemy rightly believed the Earth to be a globe surrounded on all sides by space.

The centuries passed, the work of the ancient Greek astronomers was forgotten, their writings were lost, people again believed the world to be flat, and religious geographers put paradise on the map to mark the abode of dead saints. They put it between the Rivers Tigris and Euphrates, in Asia Minor.

In the latter half of the fifteenth century people began to make very long voyages by sea. When the first of these mariners set forth into the open sea they were told that their projects were mad.

A map of the world as conceived by the Greeks

They were assured that the Earth was flat and that the World Ocean ran round its edge and fell into an abyss in a gigantic waterfall. If a ship sailed to the edge of the Earth it would fall into the abyss and be lost.

But even at that time there were scholars who, like Ptolemy of old, believed that the Earth was round like a ball and not flat like a saucer.

"All right," agreed the people who were opposed to distant travels. "We'll admit that the Earth is shaped like a globe. But if the ship sails from the top and goes down into the bottom half it won't be able to come back, all the way uphill!"

In what way were these people mistaken? They believed that they were living on top of the Earth, on top of a mountain.

And now here is a little tale.

Once upon a time there lived in the village of Upper Earth two friends, Stay-at-Home and Traveller. Stay-at-Home sat by his fireside and Traveller set off to visit strange lands for he wanted to go right round the Earth. Stay-at-Home tried to frighten him by warning him of the terrible dangers that awaited him.

"You're going to the bottom half of the Earth," said Stay-at-Home with a sigh, "and from there you'll fall on to the sky."

But Traveller was a bold man.

"I'm going, all the same," he said to his friend, "and if I don't return within three years you may believe me dead..."

And so Traveller went his way, passing through many cities and countries; he kept going in one direction all the time. Everywhere he went there was land under his feet and sky overhead. He probably would have liked to fall off the Earth into the sky and see the living God (religious people in the olden days believed that God lived in the sky). But how could he fall on the sky if it was always above his head?

"How silly we were," thought Traveller, "to call our little village Upper Earth. Now, it seems that everywhere is the top of the

Earth! How surprised my friend Stay-at-Hame will be when I tell him!"

When a year and a half had passed Traveller estimated that he had reached the opposite side of the Earth.

"That's a fine thing," he exclaimed. "Stay-at-Home and I now have our feet towards each other and our heads are pointing opposite ways!" And he was so pleased that he had proved right in his argument with Stay-at-Home that he began to walk faster and reached home three months before time.

And Stay-at-Home sat all the time by his fireside and gazed sadly in the direction in which Traveller had disappeared. At first he hoped that his friend would return, but after a time he gave up all hope.

"I knew that Traveller would fall off the Earth," Stay-at-Home repeated sadly every day.

But Traveller came home safe and sound and as happy as can be; and he came down the street from the end opposite to that from which he had left.

Then Stay-at-Home believed that the Earth was round and that people could live with their feet towards each other and their heads in opposite directions. They changed the name of their village from Upper Earth to Same-as-the-Others.

What is true and what is invented in this tale?

It is true that the Earth is round and if you go east and keep going straight on all the time you will come back to where you started from, but it will be from the west.

It is also true that in olden days many people believed they lived on the "upper" side of the Earth and that if they went to the "underneath" part they would be threatened by all sorts of dangers.

There was once a writer by the name of Lactantius who wrote:

"Is it possible that there can exist a thinking person with such an unbalanced mind as to imagine that there are people who walk with their heads downwards and their feet uppermost? That everything that lies on our Earth hangs down from it in that land? That the grass and the trees there grow downwards and the rain and hail fall upwards?"

If our Traveller had carried Lactantius' book in his rucksack to read when he was resting he would have had a good laugh at its author by the time he reached the opposite side of the world; Lactantius, though he was a writer, shared the silly fears of ignorant people.

Our Traveller would probably have said:

"That Lactantius ought to go travelling himself, then he wouldn't write such nonsense. Old Stay-at-Home and I are on opposite sides

of the Earth but we both walk with our feet downwards and our heads up. And the trees there and here all grow in the same way: roots down in the ground and the trunks and branches upwards in the air. The rain and hail fall downwards, too, from the clouds to the ground. If you think at all you realize it can't be otherwise. If the Earth is round the people all over it are in the same position like ants crawling over a melon."

What was invented in that story?

The only invention is in the way Traveller made his journey. The first journeys round the world were made by sea and they were not made as easily as Traveller made his.

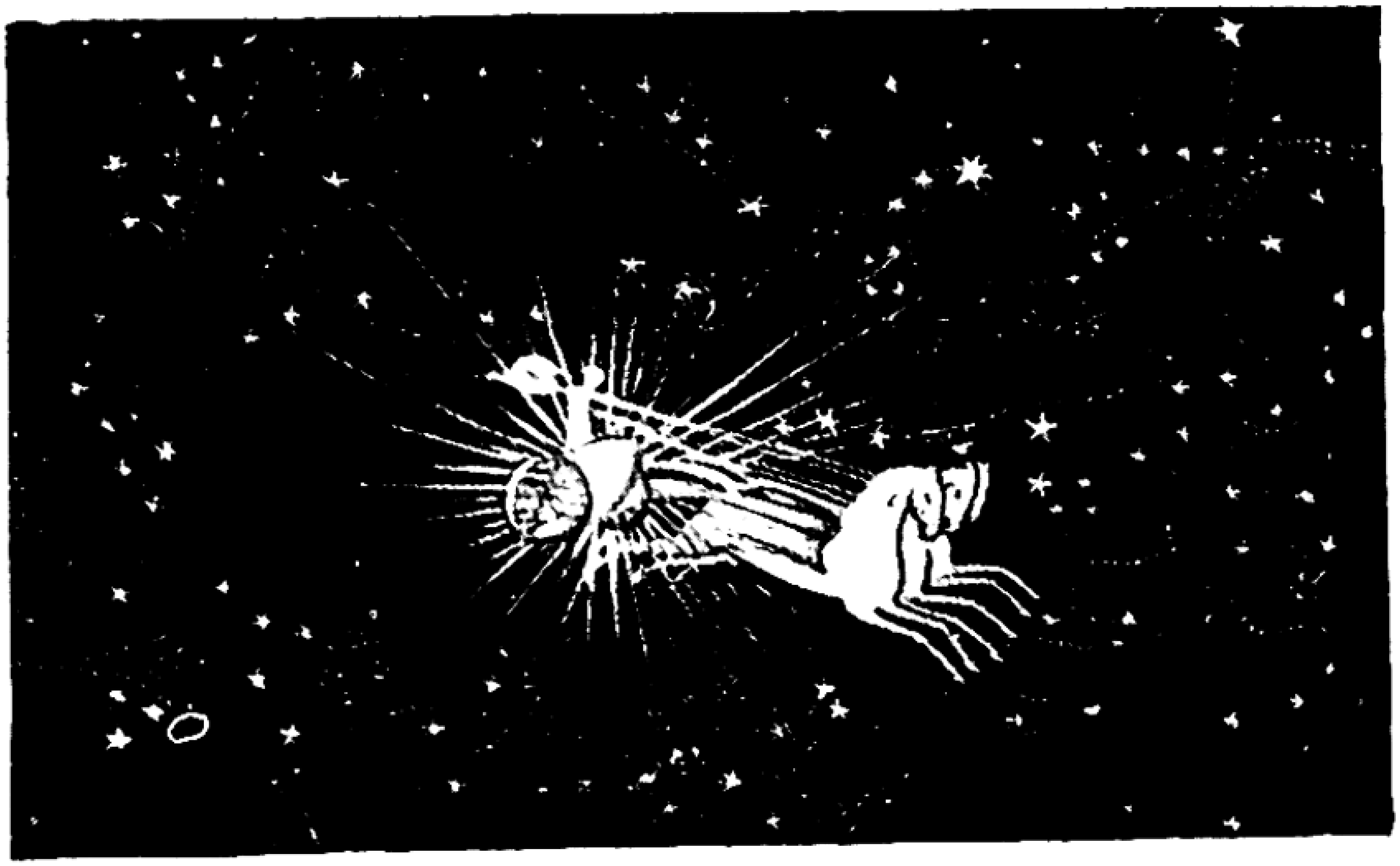
I will tell you presently how the first journey round the world really came about. But first let us turn over a few pages of the history book. They will tell us of the great battle between ignorance and knowledge, about the heroes and martyrs of the science of astronomy who did not spare their efforts or even their lives in order to learn the truth and spread it among the people.

THE LEGEND OF PHAËTHON

The ancient Greeks thought that the world was very small and that the sky was quite close to the Earth.

The story they told about the world went like this.

They believed that the world was ruled by the gods. The father and ruler of all the gods was Zeus the Thunderer who, the Greeks



Surrounded by monsters, the constellations, reckless young Phaëthon drives the Sun Chariot across the sky

believed, sent lightning down to Earth. The god of the Sun they called Helios (the Romans called him Apollo), and they believed that every morning Helios came out in the east on his well-fed, well-rested sun-horses that had spent the night underground. In the fiery chariot drawn by his sun-horses Helios made his daily journey across the sky and in the evening went back underground to rest the tired horses.

Young Phaëthon, the son of Helios, longed to take a ride across the sky in his father's chariot. For a long time Helios would not allow him, but at last he agreed. The excited young Phaëthon climbed into the shining chariot, took the reins in his hands and set off through the constellations scattered at random all over the sky.

Phaëthon had to drive past the group of stars known as the Scorpion. This monster was such an awful sight that the horses took fright and dashed off the road. The boy's hands were not strong enough to hold the fiery steeds and an awful accident happened: the Sun Chariot left the proper road and drew close to the Earth. Brilliant

hot rays flashed out from all sides of the chariot and they burned up everything on Earth. Towns and villages were razed to the ground, the forests, fields and meadows caught fire. . . .

In terror people fled from their burning houses and prayed to Zeus, the Father of the Gods, to save them from the terrible catastrophe. But how could the fiery chariot be stopped? Who could catch the swift sun-horses?

Zeus cast a flash of lightning at Phaëthon and the youngster fell dead from the chariot. The frightened horses stopped. Helios ran to the chariot and brought it back to its usual road. The fire on Earth came to an end.

When the people recovered from their fear they looked up at the sky and saw the Sun in its usual place. They hurried to make sacrifices to Zeus for saving them.

Even in those distant times, however, not everybody believed such stories.

There was a great scholar by the name of Pythagoras who lived two thousand five hundred years ago; he said that the Earth is like a ball and that there is no top or bottom to it.

Another Greek scholar, Aristotle, who lived two hundred years after Pythagoras, tried to explain the motion of the Moon, Venus, Mars and other planets. He believed that the Sun, the planets and the stars revolved round the Earth. But, he wondered, what moves them and how are they held up in space?

Aristotle pondered over it and thought it out this way. Above the Earth there are eight hard and transparent crystal heavens. The nearest one is the Heaven of the Moon; it revolves round the Earth and the Moon is fixed to it. Next comes the Heaven of Mercury and then the Heaven of Venus; after this come the other heavens or heavenly spheres (sphere comes from the Greek word for ball or globe) of the Sun, Mars, Jupiter and Saturn. The stars, he thought, are all fixed to the Eighth Heaven.

When Aristotle had produced this theory, the Aristotelian System, he asked himself what made the eight heavens revolve? The great scholar did not believe in the tales told by the ignorant priests about the sun-god Helios and all the other gods that were supposed to live on Mount Olympus.

A sailing ship is moved by the force of the wind; a man moves by the power of his muscles; a cart is drawn by a horse that also uses

the strength of its muscles. Aristotle decided that there must be a ninth sphere, a kind of motor that moved all the others; he called this the "primary motor," or "prime mover."

You must not laugh at Aristotle's system: in its time it served a useful purpose—it cast the gods out of the Universe and destroyed religious superstitions.

The priests realized this. They turned angrily upon Aristotle:

"Aristotle says that the Sun is not the golden chariot of Helios who drives his fiery horses across the sky, but that it is a heavenly luminary that moves round the Earth by itself. Aristotle is an atheist, an enemy of the gods, and he must be punished!"

They drove Aristotle in his old age from his native land and he died in a foreign country.

PTOLEMY AND HIS THEORY OF THE UNIVERSE

Now you know that people in ancient days believed the sky to be a hard, transparent crystal bowl: they believed that all the stars revolve round the Earth like the shining heads of nails hammered into the bowl. In ancient days it was thought that the stars were fixed and could not move but, as we shall see later, this is not true.

But people watching the sky also saw bodies moving among the stars; some of them moved rapidly, others more slowly. And there was something that worried the ancient astronomers: as these bodies moved across the sky they went first in one direction and then turned round and went back in the other direction, they moved in reverse.

These few bright bodies were like fireflies crawling among the gleaming nailheads; they appeared first in one and then in another part of the sky. This is why the Greeks called them "planets" which means "wandering stars."

Today we give the name of "planets" to those bodies that do not give off light themselves but reflect the rays of the Sun. If the Sun were suddenly to go out, then the Moon, Venus, Mars and the other planets would not shine any more.

The stars are fiery heavenly bodies that shine with their own light. The Sun is the nearest star to us and it gives us the light and

heat that make life possible. In olden days the Sun was wrongly called a planet.

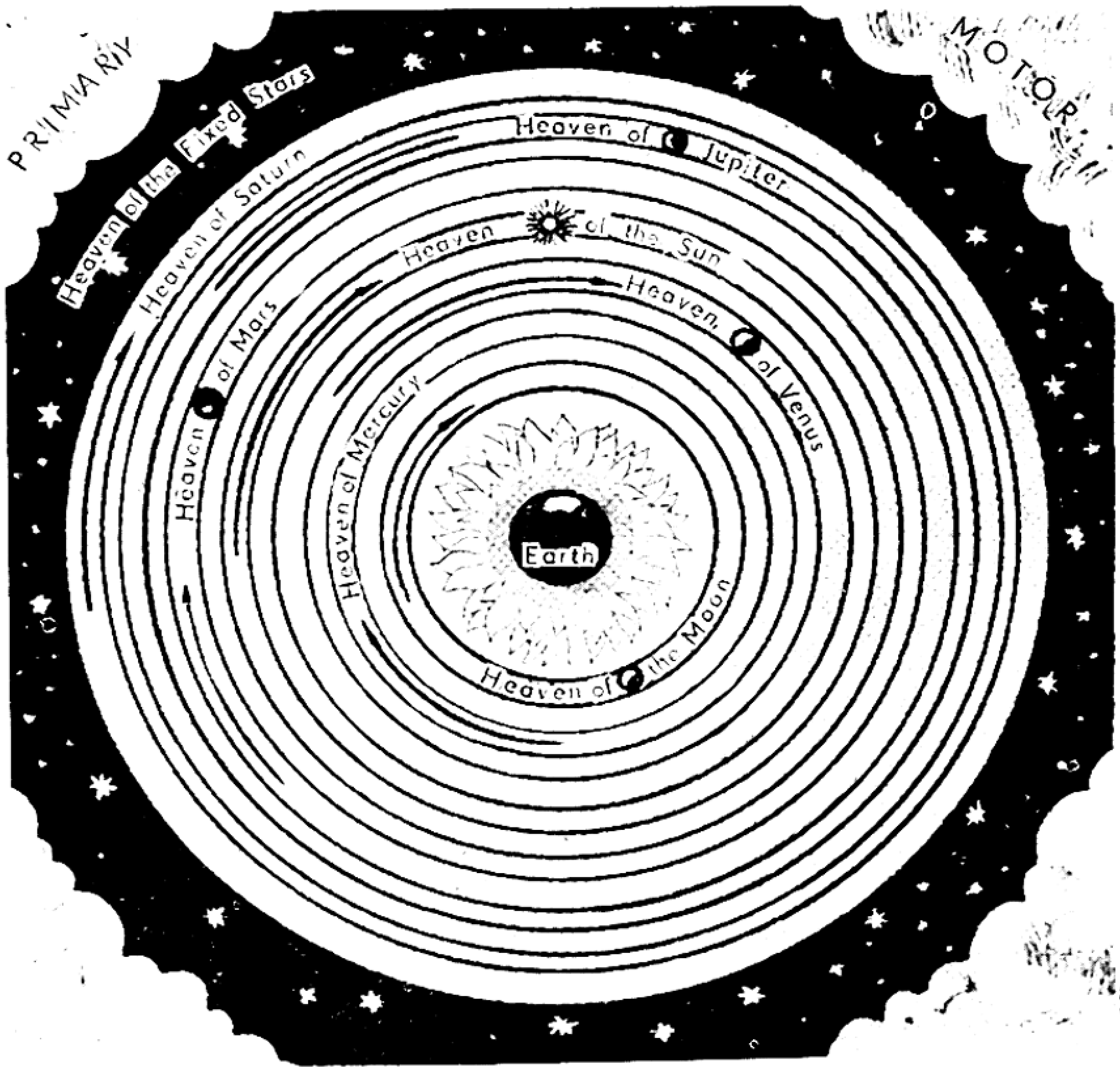
I have already told you how Aristotle tried to explain the structure of the Universe. A hundred years after his death there lived another Greek scholar, Ptolemy, who built up a new theory of the Universe.

This drawing was made several hundred years ago. The traveller has reached the firmament surrounding the Earth, found an opening in it and is admiring Aristotle's crystal spheres

Ptolemy did not believe in Aristotle's crystal heavens. He taught his pupils that the heavenly bodies move round the Earth in empty space.

The Ptolemaic system was so complicated that he had to admit: "It would be easier for me to move the planets myself than to explain how they move."

The Ptolemaic system, however, made it possible to predict how the planets would move in the sky. Although he was mistaken in his beliefs Ptolemy was, for his day, a great astronomer, and

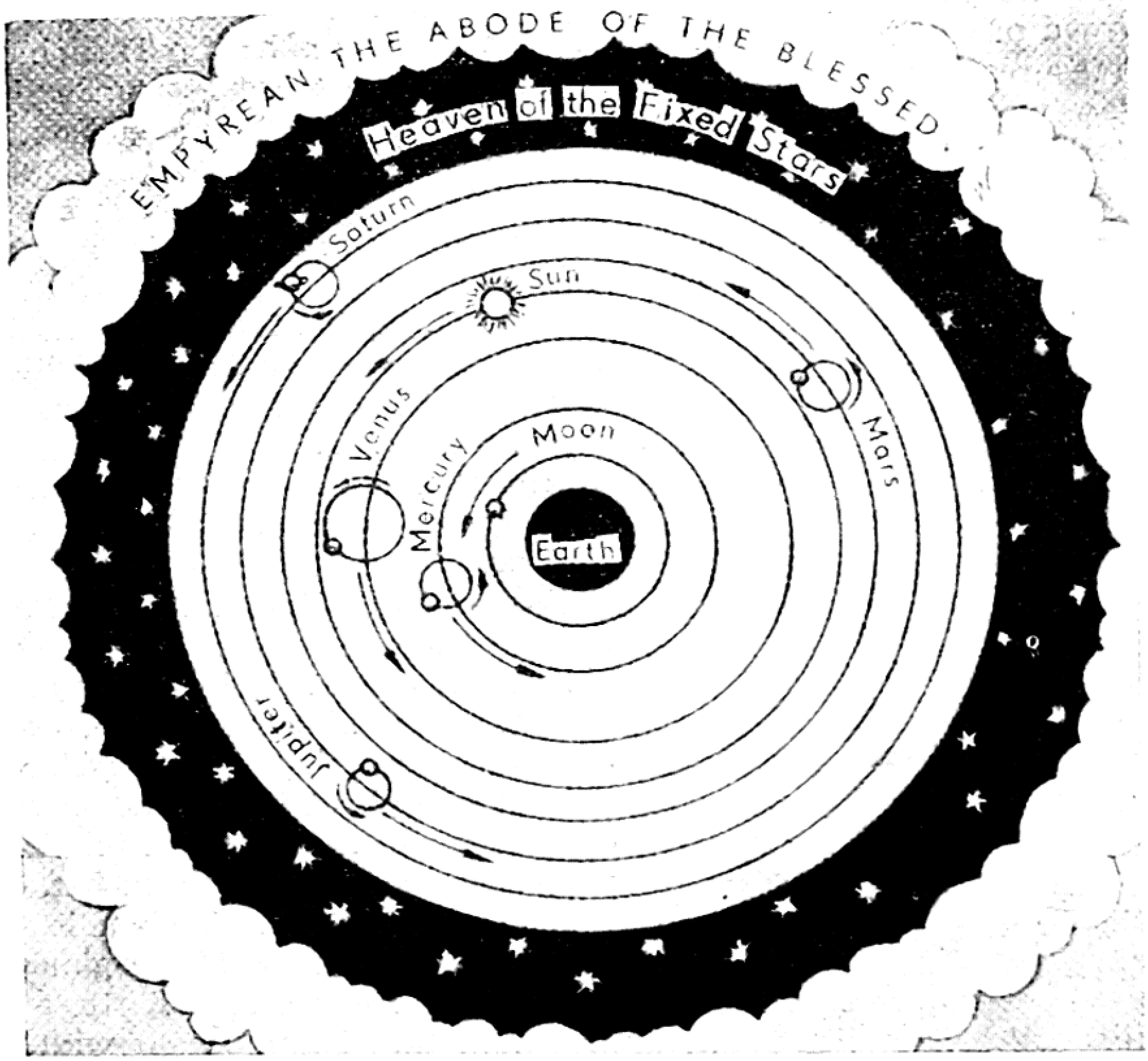


Aristotle's conception of the Universe: the planets are attached to the crystal heavens

his system was a great step forward compared with that of Aristotle.

The Ptolemaic system was later recognized as true by the Christian Church and it became dangerous to cast doubts on its truth.

The Christian religion fought against any kind of free thinking. The Christian bishops and priests were opposed to science; they regarded both the scientists and the books they wrote as dangerous enemies.



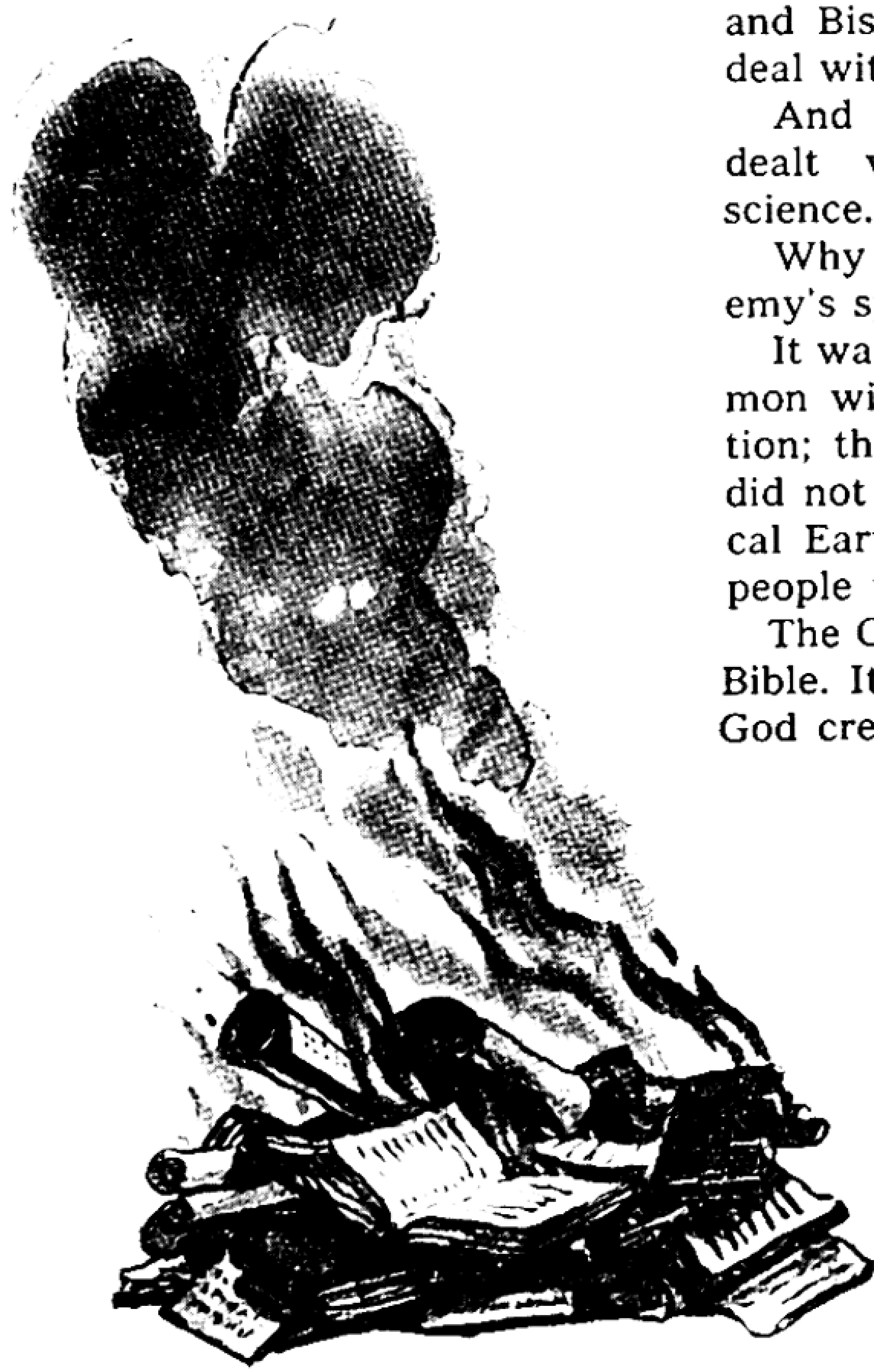
Ptolemy's conception of the Universe: the planets revolve in empty space

Here is what happened in the city of Alexandria, where Ptolemy had lived, two hundred years after his death. In that city there was the biggest library of the ancient world; it contained over 400,000 books, all written by hand. Even today such a collection of books would be regarded as a big library.

The Alexandrian library contained the works of scholars from all over the ancient world on medicine, history, geography, astronomy, mathematics and other subjects. Scholars went there from all countries to study.

In the year 391 this library was set on fire and destroyed by a crowd of Christians who had been incited by the bishop Theophilus. Treasures of untold value were lost to the world. The manuscripts were worth more than gold or diamonds because they could not be replaced.

About twenty years later an enraged crowd tore to pieces one of the most remarkable women of the ancient world, Hypatia, the first woman teacher of astronomy and mathematics. Hypatia was a seeker after truth, she fought for genuine science against Christian superstition, and Bishop Cyril sent assassins to deal with her....



And that is the way the Church dealt with men and women of science.

Why did the Church favour Ptolemy's system?

It was because it had much in common with the biblical story of creation; the only thing the churchmen did not like about it was the spherical Earth and they ordered religious people to consider the Earth flat.

The Christian theory is given in the Bible. It says that in the beginning God created Heaven and Earth and the Earth was without form, and void. And then God divided the light from the darkness. The Earth, therefore, had been the centre of the Universe, as it was in Ptolemy's system, from the very beginning.

On the second day God made the firmament and called the firmament Heaven and this solid Heaven,

or firmament, divided the waters above from the waters below. The "waters above," the heavenly waters, were those that fall to Earth as rain. Ancient people believed that these waters collected somewhere above the heavens and fell to Earth through a lot of tiny holes.

On the third day God divided the dry land from the waters and commanded vegetation to appear.

It was only on the fourth day that God created the Sun, Moon and stars "to give light upon the Earth."

On the fifth day he created the crawling things, the fish and the birds and on the sixth, the animals and man.

When one reads this biblical tale one is amazed how many foolish things and contradictions there are in it. It is not worth while discussing all of them. Let us ask only one question: light appeared on the first day and the Sun, Moon and stars on the fourth day—then where did the light come from? And if there was neither a Sun nor a Moon how were the first three days counted?

The churchmen did not pay any attention to these contradictions. They said: "After Jesus Christ no other sciences are necessary!" The Church Fathers took to Ptolemy's ideas because they did not go very much against the Bible story. When it had been proved that Ptolemy's system was incorrect the princes of the Church still stuck to it and persecuted those who refused to believe in it.

The Fathers of the Christian Church taught their flock that there is a place where sinners are horribly tormented, a place called Hell that lies deep down in the bowels of the Earth. And they put Paradise, the abode of angels and saints, where Aristotle had placed his "prime mover."

Work was found for the angels in heaven, by the way. The priests taught the people that it is the angels who move the planets. A book written in the 15th century by G. Fontana was even called: *The Book of the Natural Things Contained in the World and of the Angels Who Move the Heavens.*

The churchmen disagreed on one point only: how did the angels make the planets move?

Some of them said: "The angels carry the heavenly luminaries on their backs in the way a peasant carries a sack of grain to the mill."

Others said: "No! The angels roll the luminaries round the sky in the way porters roll a barrel of beer to the cellar!"

"Neither the one nor the other!" exclaimed a third lot. "The angels pull the luminaries like a horse pulls a cart!"

A scholarly monk, Riccioli, who studied the stars and the planets, wrote: "When moving a star, the angel watches what his companions are doing and keeps to a definite path so as not to collide with them."

The church also taught that the angels got the clouds ready and sent down rain and snow from them, that they had charge of the weather and distributed the heat and cold.

The Ptolemaic system was believed to be the true one for fourteen hundred years. But the great explorers of the late 15th and early 16th centuries, Columbus, Magellan and others, made long journeys by sea that greatly extended the boundaries of the known world of that time.

CHRISTOPHER COLUMBUS AND HIS DISCOVERIES

Christopher Columbus, an Italian, born in the city of Genoa, lived in Portugal in his youth and took part in distant voyages made by Portuguese seafarers. By the time he was thirty-five Columbus had earned himself the reputation of a good mariner. That was the time when the idea of journeying to India and China by sea first occurred to him.

The land road to those rich countries was a long and difficult one and it went eastwards all the way. The idea that the Earth is shaped like a globe had by that time gained considerable ground, and Columbus thought that if he sailed westward he would still come to India and China.

Columbus did not know that his way would be barred by the huge continent of America. Nor did he know that the distance to China by sea was much longer than by land although it was easier travelling; in those days, indeed, the real size of the world was unknown and people believed it much smaller than it really was.

Columbus had great difficulty in getting permission to fit out an expedition. In Portugal nobody had any faith in Columbus' idea. He went from there to the neighbouring country of Spain and after years of effort and worry he was given command of three tiny vessels. On August 3, 1492 he set sail on these little ships (*caravelas* they were called in Spanish) from the harbour of Palos.

On all three ships—*Santa Maria, Niña* and *Pinta*—there were only ninety officers and seamen. But neither the small number of men nor the distance of the voyage scared the admiral.

He was rewarded for his confidence in the success of his undertaking. After many weeks sailing the verdant coast of Guanahani Island met his eyes. Guanahani was the name given to the island by the people who lived there but Columbus gave it the name of San Salvador, the Spanish for "Holy Saviour."

Two weeks later Columbus discovered the big island of Cuba and after that the island of Haiti.

Columbus was convinced that the islands he had discovered were part of India and he went back to Spain with that information.

Very soon Europeans learned that the newly-discovered islands were not India and that behind them lay a huge continent that was quite unknown to them. Nevertheless, the islands kept the name Columbus had given them, but were called the West Indies and the real India became known as the East Indies (today it is called simply India). The inhabitants of India are Indians and the native inhabitants of the West Indies and America are also called Indians; thus the people living in places separated by huge expanses of ocean have been given similar names owing to the mistake made by Columbus.

The huge continent that lay behind the islands of the West Indies was not given the name of the great seafarer to whom its discovery was due. It was called America after the explorer Amerigo Vespucci who made a number of voyages to the New World (as it is still often called today). Somewhat later Columbus described his voyages in letters to his friends.

Columbus died in poverty, forgotten by almost everybody, in 1506.

A few years later, a squadron of ships commanded by another great explorer, Fernando Magellan, made a voyage round the world. Now I shall tell more about this voyage.

THE FIRST VOYAGE ROUND THE WORLD

A squadron of five tiny vessels set sail from the Spanish harbour of Seville on September 20, 1519.

The ships were called *San Antonio, Trinidad, Concepcion, Vittoria* and *Santiago*. Two hundred and thirty-nine officers and men set forth on the voyage and but few of them returned.

The Spanish squadron was commanded by Admiral Magellan. He was not a Spaniard by birth but came from the neighbouring country of Portugal.

Fernando Magellan set himself a difficult task, that of finding the way from the Atlantic Ocean to the Pacific Ocean.

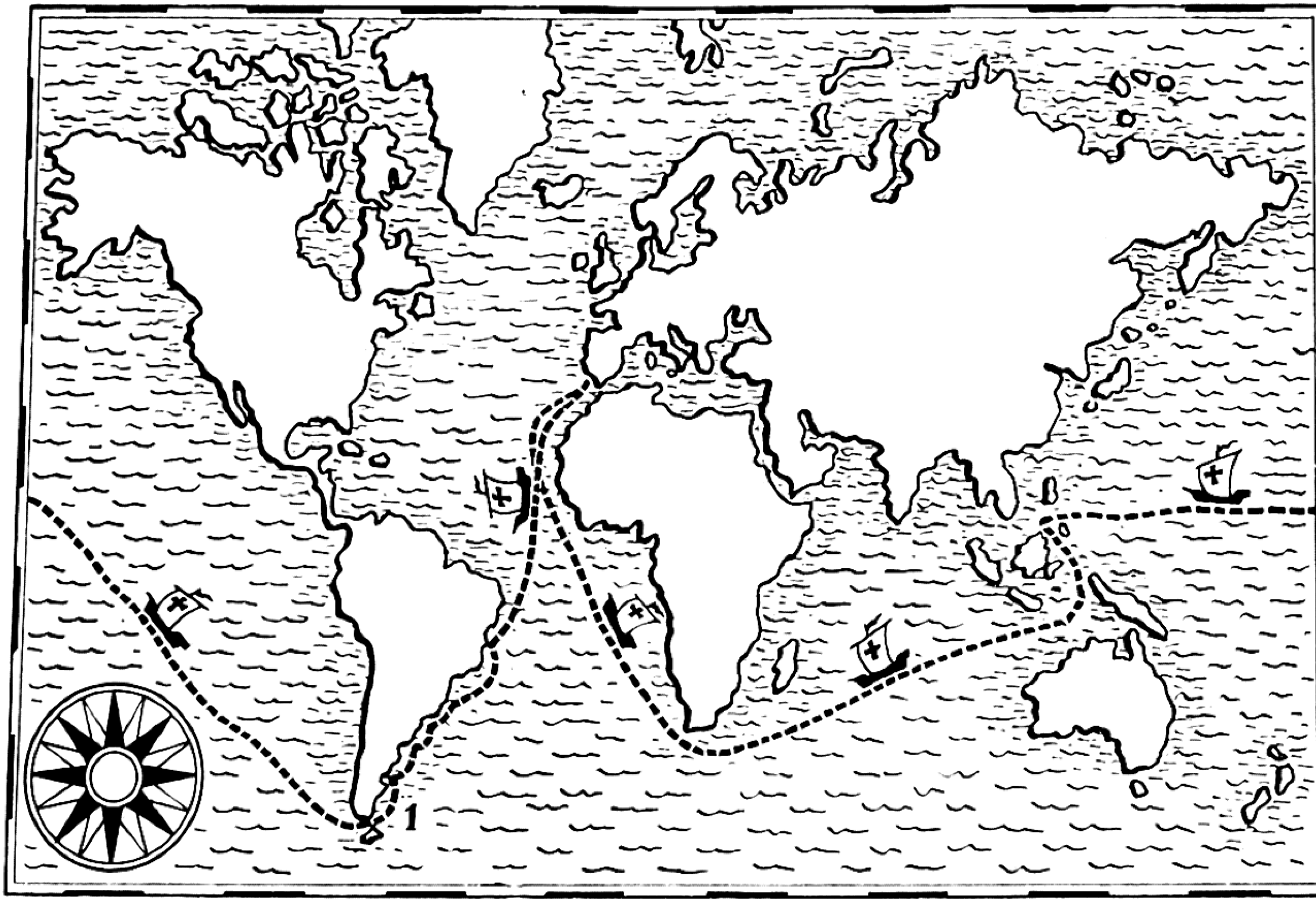
Take a glance at the map. Between the two oceans lies the huge continent of America, from the ice-bound waters of the Arctic Ocean to the cold Antarctic seas. The ocean to the west of America had by that time been discovered and called the Great Southern Sea.

Other mariners had tried to reach the new, unknown ocean before Magellan, but wherever they tried, from the equator to the north and the south, they found the continent of America barring their way. It had become a common belief that it was impossible to sail from the Atlantic Ocean into this Great Southern Sea.

Magellan did not agree with this opinion. He was sure that there would be a strait somewhere in the south that connected the two oceans. He undertook to find that strait if he were given ships and men. He tried hard for many years to get them in Portugal, his own country, but without success. He had to leave his native land and go to Spain. There he found people who believed in him and he was appointed admiral of a squadron.

And that is how the Portuguese Magellan (or Magalhães in Portuguese) came to be in charge of a Spanish expedition that set out on a journey such as no man had ever before undertaken.

Magellan had to pay a heavy price for his high appointment and for the tremendous riches that awaited him in the event of his success; a contract that he concluded with the King of Spain appointed him governor of all the new lands he discovered and one twentieth of the profit accruing from them. The proud Spanish captains who were placed under the command of a foreigner were jealous of Magellan and swore to do away with him when opportunity offered.



Magellan's voyage round the world

Even before they set out, Magellan's enemies did everything they could to hinder him; they would not provide the money to equip the expedition and even made an attempt on his life. He was given old rotten *caravelas*; his crews were made up of the outcasts of all nations, men who had fled their native countries to escape punishment for various crimes.

Magellan, however, did not give in. He overcame all difficulties; he obtained enough money to buy food and equipment for two years, had the ships repaired and trained the crews.

And why, indeed, was Magellan appointed to fit out an expedition to distant countries?

Magellan dreamed of convincing all doubting people that the Earth was round like a ball, but in those days there were but a few scholars who were really interested in the shape of the Earth; the kings, princes and merchants did not worry about it at all. They were attracted by the possibility of acquiring enormous profits in the event of Magellan's expedition proving successful.

You might think it funny, even queer, if you heard a shopkeeper say:

"You owe me twenty peppercorns for the things you have bought."

There was a time when pepper was used as money, when debts were paid in pepper, when taxes were paid in pepper and when houses, farms and ships could be bought for pepper.

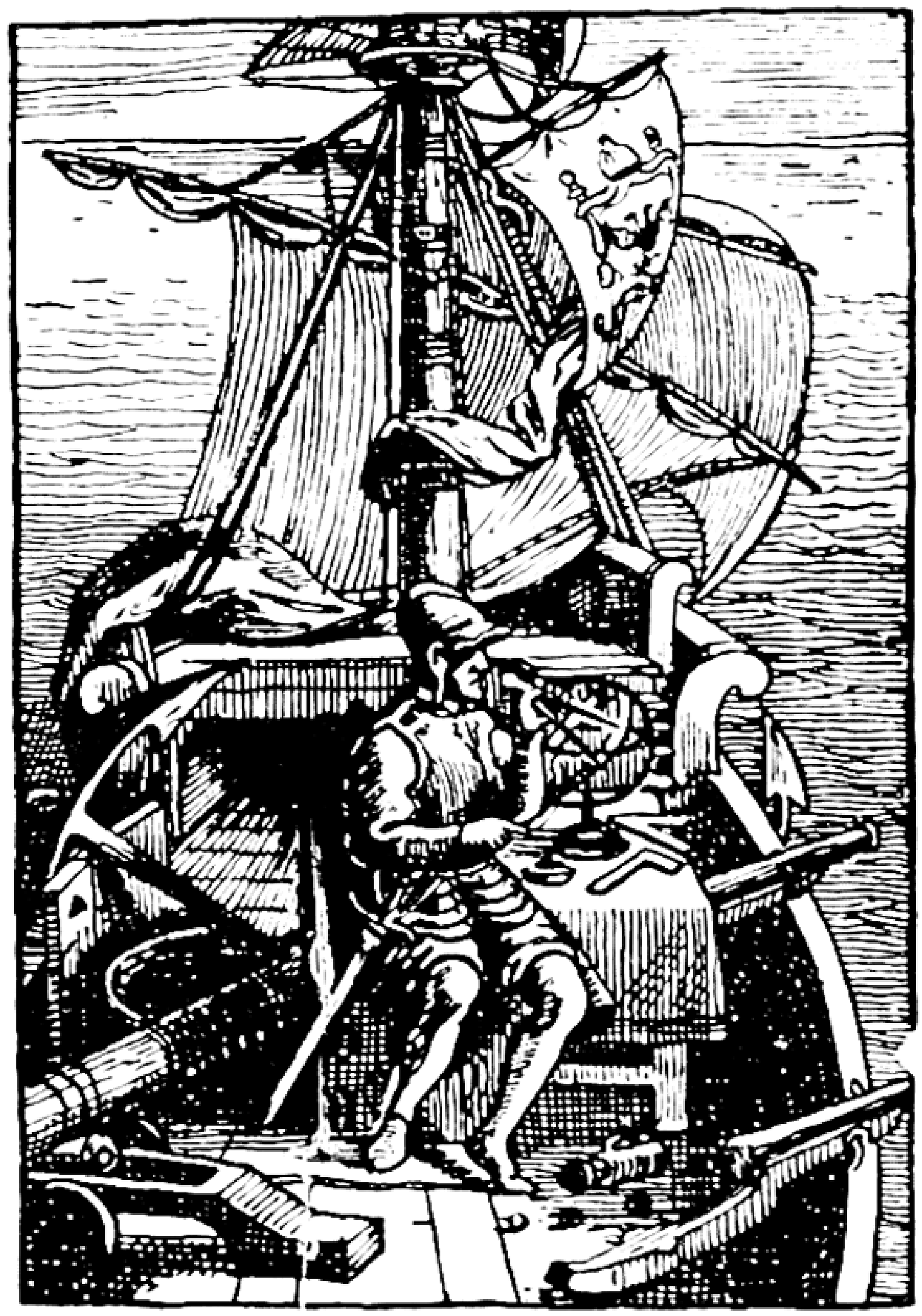
Today rich men are sometimes called moneybags, but in olden times the rich man was a "bag of pepper."

Those were the times when Magellan set out on his famous journey. The spices of the East—pepper, cinnamon and ginger—were used in the rich man's food: they gave the food a sharper and more delicate taste, and tasty food is good for the digestion. The spices were weighed on very fine apothecary's scales and every grain was of great value. The Eastern medicines, such as camphor, were also highly valued, but in the countries where they grew, in India and the Moluccas Islands (the Spice Islands) these things cost no more than oats or peas did in Europe.

Why did the Eastern spices and medicines cost so much in Europe? Because the road to Europe was a long and difficult one: the merchants who brought the spices from the East were menaced by

storms and whirlwinds, they could be killed by pirates at sea or by robbers on land; they had to pay big tolls to the rulers of the countries they passed through on their way home. The merchant's journey from the distant East to Europe lasted two or three years—do you remember Marco Polo and Afanasy Nikitin?

It had become more difficult, almost impossible, in fact, to reach the East after the Turks captured Constantinople in 1453. And that is why a pinch of pepper cost more in Europe than a barrel of the same pepper in Malaya.



Magellan during his famous voyage round the world. He is seated in the stern of his ship surrounded by the instruments used to determine the ship's position. (16th century drawing)

When the rich Spanish merchants sent Magellan off on his voyage they hoped he would find a quicker and safer route to the Spice Islands. The Spaniards, furthermore, hoped to take possession of the Moluccas Islands. That is the only reason they had for spending money on the equipment of Magellan's expedition.

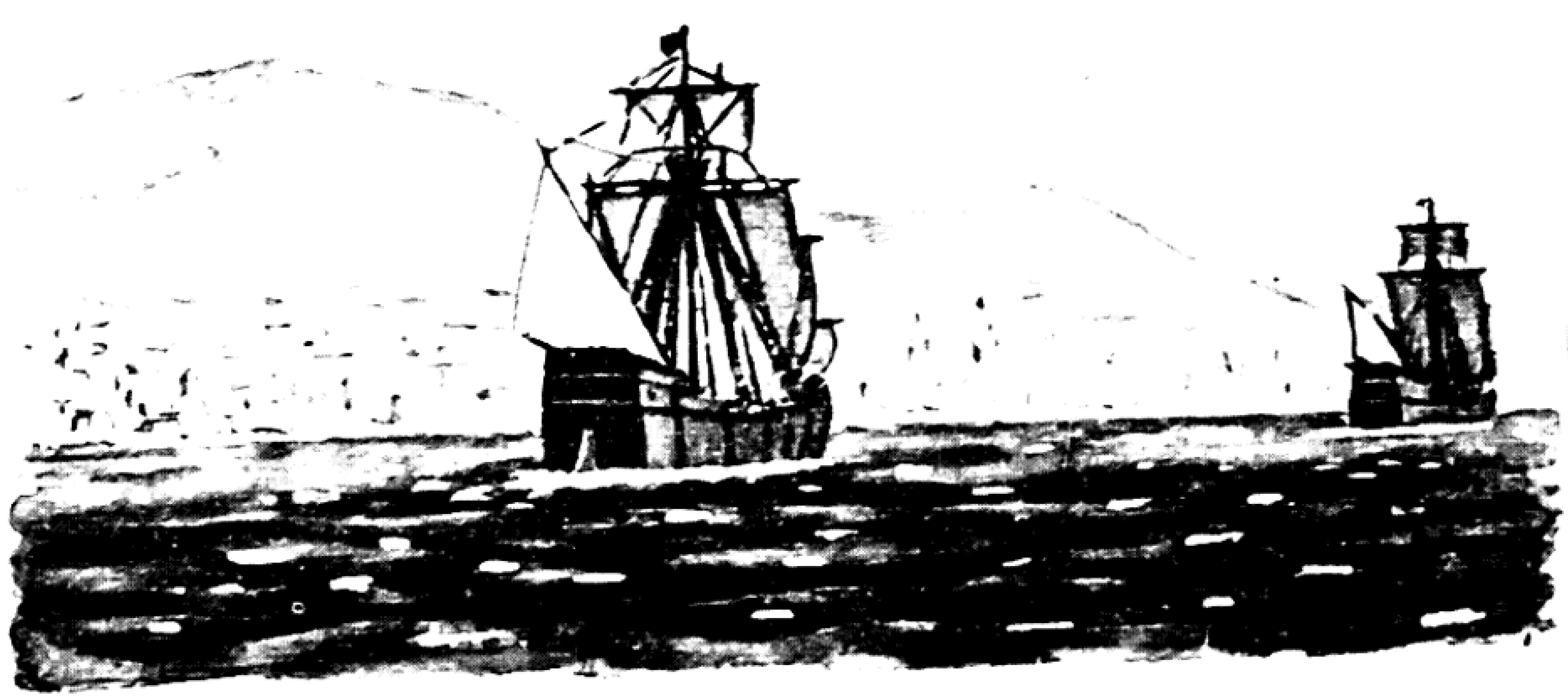
The squadron sailed as far as the coast of America without any particular adventures, although the Spanish captains of the vessels *San Antonio, Concepcion* and *Vittoria* all the time intrigued against Magellan and tried to sow discontent among the crews of different nationalities.

The chief difficulty began when the vessels reached the American coast. Magellan assumed that there must be a strait between the two oceans, but he had no idea where to look for it. He had to sail into every bay, into every inlet to find out whether or not the mysterious strait began from there.

Such a method of exploring took up much valuable time. Winter, the cruel cold winter of the Southern Hemisphere, was drawing nigh and the mariners making for the south polar seas were themselves sailing towards it.

Magellan realized that it would be madness to continue his voyage in winter because they would all perish from the terrible winter storms that raged over the cold waves of the ocean. The five ships anchored in a bay that was protected from the winds, but it was one of the most desolate spots on the face of the Earth. Cold, leaden waves beat against the sides of the ships. The shore was bare, not a tree or a bush in sight. Even the birds left that forbidding region before the onset of winter.

The sailors were sullen; they had been angered by the admiral's order

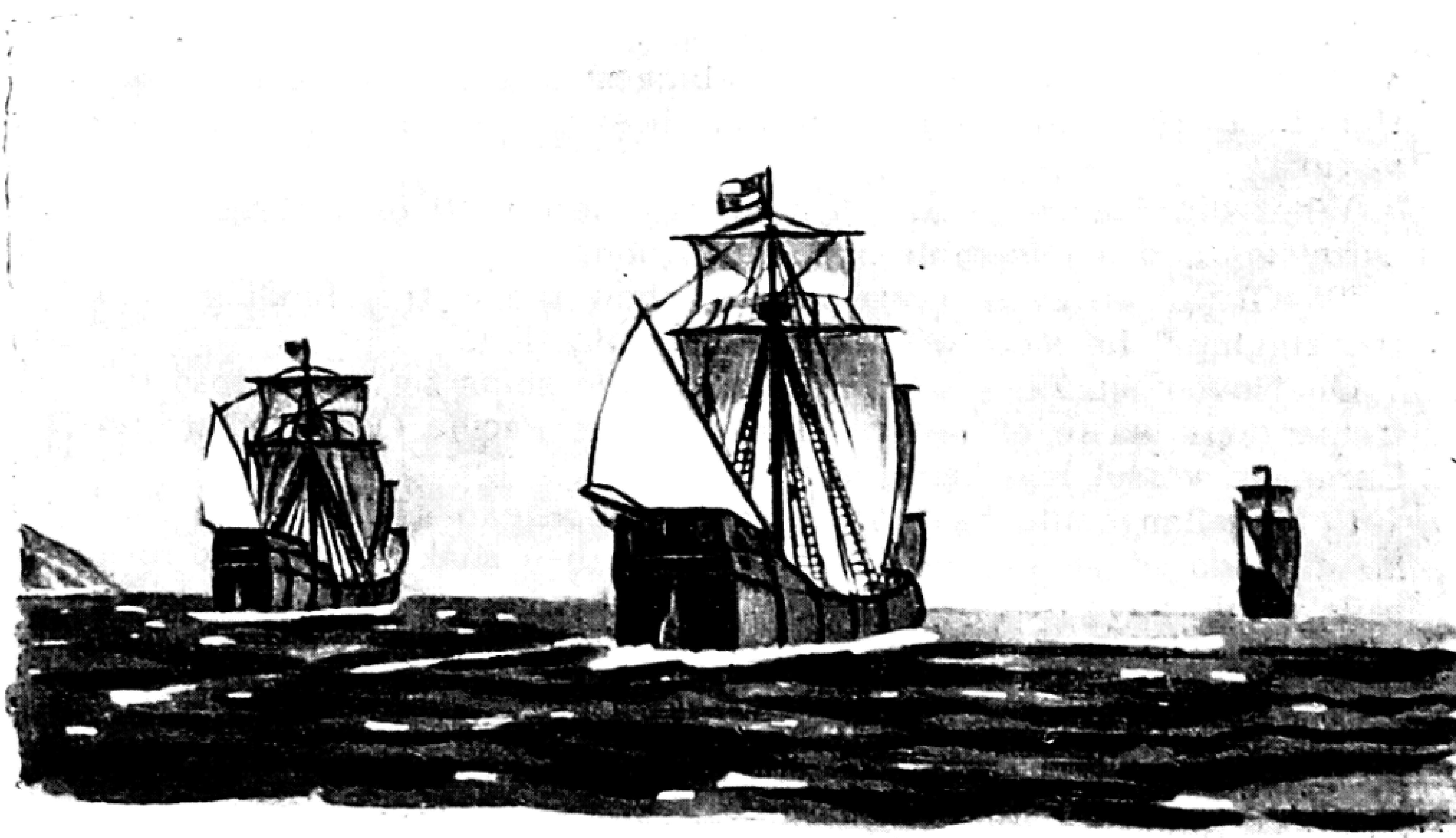


to reduce their rations of food—Magellan was afraid there would not be enough left to continue the voyage. The Spanish captains took advantage of the discontent of the sailors and raised a mutiny. Magellan suppressed it and punished the ringleaders. After that nobody dared come out openly against Magellan, but the Spanish officers hated the admiral and were secretly hostile to him.

After wintering for five weary months the vessels again set sail in a southerly direction to find the mysterious strait.

Winter was over but the squadron's misfortunes continued. The fastest of the five ships, the *Santiago*, was lost during the reconnaissance of an inlet. A storm cast it on to the shore and it was wrecked. The crew were rescued and distributed among the other ships, and the squadron sailed on. At last came the long-awaited day of triumph! As they rounded a high cape the seafarers saw a gloomy strait that bit deep into the continent; its waters were stormy and were lashed by a strong wind.

Magellan sent two vessels to reconnoitre. A few days later the vessels returned, their cannons firing a salute, their masts dressed



with flags and the sailors shouting lustily. The great discovery had been made, the mysterious strait had been found!

Magellan was overjoyed. Their tremendous labour and their privations had not been in vain, not for nothing had they overcome all difficulties and obstacles, not for nothing had he punished the disobedient Spaniards—as he had foreseen, the channel existed and he had found it!

The channel was later named the Strait of Magellan in honour of the great explorer. You will find that name on the map of South America today.

The four remaining ships continued their way slowly and cautiously.

They sailed on for a whole month through the newly-discovered strait. At last they entered an ocean that Europeans till then did not know. Grim Magellan's eyes filled with tears of joy.

"Westward! Cram on all sail for the Spice Islands!"

But another misfortune befell the dauntless mariner when he was on the eve of success; treachery almost ruined his whole voyage. The first mate of the *San Antonio* led a mutiny of the crew and secretly turned the *San Antonio* back to Spain.

The traitor dealt Magellan a hard blow: the main food supply was on board the *San Antonio*, the biggest of the ships, and it was the best food that Magellan had been saving for the further voyage.

What did Magellan do when he was left with only three small *caravelas* and a miserable supply of food?

"We'll sail on even if we have to chew the leather binding from the rigging!" he said with great determination.

On November 28, 1520 Magellan's three ships set out across the tremendous waste of waters known as the Pacific Ocean where no European vessel had been before.

If Magellan could have foreseen the huge expanse of ocean that his dilapidated, sea-battered vessels, with their shaky masts and torn sails would have to cross, it is doubtful whether he would have taken the risk. But he did not know.

Before Magellan's voyage people had no idea of the real size of the world. The admiral thought that a voyage of three or four thousand kilometres would bring him to the Spice Islands. Actually eighteen thousand kilometres divided him from the islands!

The new ocean greeted the travellers with wonderful weather: the sky overhead was cloudless, the sun warmed the sailors who had suffered such a long, cold winter, and a soft breeze sent the ships sailing steadily westwards. Magellan called this peaceful sea the Pacific Ocean.

It later turned out to be far from peaceful; so great is its size that sailors also called it the Great Ocean—and it still bears the two names in Russian today.

Week followed week and still the desired land was not sighted. A month passed and then a second and still the majestic empty ocean surrounded the three little vessels on all sides.

There was hunger on the ships. It turned out that Magellan's enemies had foisted on to him boxes of rotten ship's biscuits instead of fresh provender at the time he had fitted out his expedition. And to make matters worse the rats had gnawed holes in the boxes and were eating up the food. The sailors began a furious hunt for rats and when one was captured it was treated as a tit-bit and eaten ravenously.

The wine had given out long before and the fresh water kept in casks had soured. It gave off such an evil smell that it was disgusting to the taste and the men held their noses when they drank it.

Magellan's gloomy forecast came true: they cut the leather bindings from the rigging to eat! First they lowered it overboard to soften in the salt water for several days and then cut it up, roasted it and swallowed it without chewing it; it was, indeed, so tough that it could not have been chewed. The pieces of leather caused them terrible pains in the stomach.

For three months they journeyed without sighting land and the sailors began to die of hunger. They threw the dead overboard and they were immediately devoured by voracious sharks.

The men were seized with indescribable horror: it seemed that an unescapable death awaited them in that boundless watery desert. The sailors were sure that they would sail on and on and never see land again.

Magellan, however, realized that he could not turn back. Ahead of them, sooner or later, there would be islands, but it was impossible to return, they had neither the strength nor the provisions for the long journey.

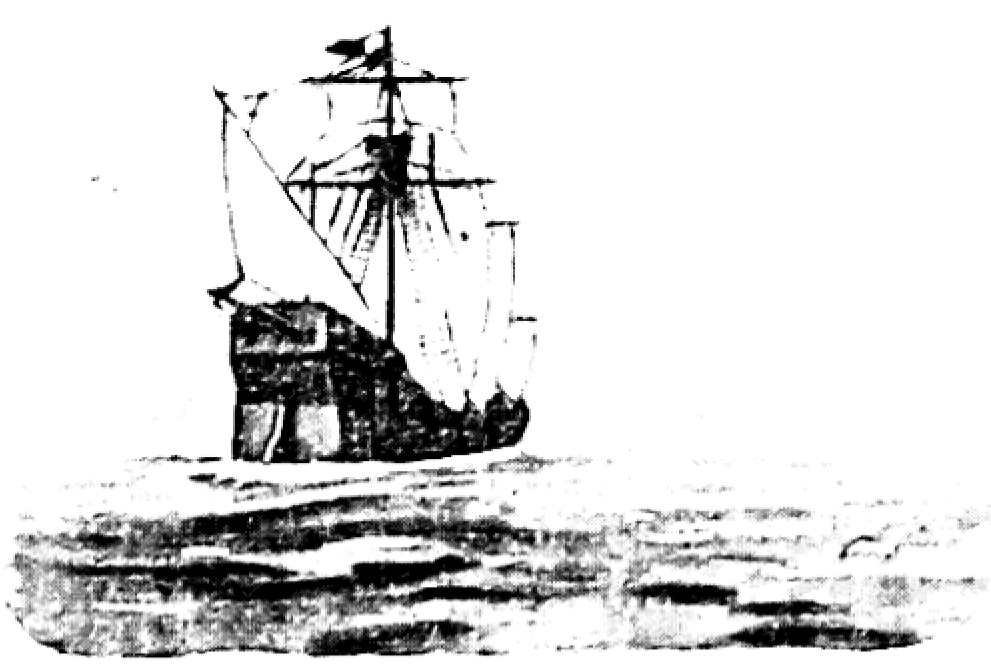
After more than three months of that terrible voyage the sailors sighted land—stern bare rocks without a drop of fresh water or a sign of vegetation. Nevertheless, it gave them encouragement for it meant that the desert of waters was coming to an end and soon there would be luxurious islands with water and food on them. And they were not disappointed!

On March 6, 1521 the jubilant sailors saw an island, a real island, with palms and streams of sweet water, pure cold water that they had thirsted for so long. The island was inhabited and the inhabitants kept cattle. They would get fresh meat to eat! The lengthy privations of the bold seafarers were over.

It was now safe to assume that the calamities that had beset Magellan's expedition were over, that they would sail calmly and peacefully from island to island, from harbour to harbour and that the three remaining vessels would return to Europe in triumph.

Such, however, was not the case. Magellan and his fellow-travellers still had many misfortunes ahead of them, misfortunes that they brought upon themselves. From then on nature was not to blame for catastrophes; the fault lay with the sailors' greed for easy gain and their hunger for easy conquests.

Magellan intervened in disputes between the petty kings on the Philippine Islands: he wanted to show them the power of European weapons. Accompanied by sixty men clad in armour he gave battle to a thousand natives of the island of Matan who were armed only with bows and spears. Magellan met his death in that battle.



Thus died the famous seafarer without having finished that to which he had devoted his life.

After the death of Magellan and many of his men, the Spanish seamen wandered for a long time among the islands scattered between

Asia and Australia. By that time only two vessels remained to them, *Trinidad* and *Vittoria*. They had had to burn the decrepit *Concepcion* to prevent its falling into the hands of the natives.

They then discovered that *Trinidad* was in such bad condition that it would not be able to return to Europe. It was decided to leave *Trinidad* for a complete refitting and set out for Europe on *Vittoria* alone; its crew consisted of forty-seven men under Sebastian del Cano, the best mariner among the survivors.

Trinidad, incidentally, did not get back to Europe. It was lost after a long period of cruising among the islands. Most of the crew were lost with the ship, only four finally reaching Spain.

Vittoria, with provisions and fresh water on board, set out for home.

The voyage was a terrible one. The food spoiled, the water went sour. There were 26 tons of spices on board, a gigantic fortune in those days. The Spaniards had acquired the spices by barter on the Eastern islands; spices, however, are not food; they can only be used to flavour food and they had none to flavour.

Vittoria reached the harbour of Seville, in Spain, on September 8, 1522. There were only eighteen men standing on deck beneath the unfurled Spanish flag. The first voyage round the world had lasted three years, all but twelve days.

The Spanish merchants were satisfied. The twenty-six tons of spices more than paid all the costs of the expedition and the price of the five ships.

It is true that more than a hundred and sixty officers and men had died but that did not worry the merchants; the men's lives had not cost them a cent.

Thus ended Magellan's famous expedition.

For the first time it had been proved beyond all dispute that the Earth is round and can be circumnavigated.

It is difficult for us to imagine the astounding effect Magellan's discovery had on his contemporaries.

Look again at the map of the world. Before the time of Columbus, Europeans did not know of the existence of America; before Magellan's time they did not know the real size of the Pacific Ocean. Now remove America and the Pacific Ocean from the map. How big is the part left? That remaining part is what was believed to be the whole world by people living four hundred and fifty years ago, before the remarkable voyages of Columbus and Magellan.

NICOLAUS COPERNICUS, THE GREAT POLISH ASTRONOMER

The great voyages made by Columbus, Magellan and other mariners changed the map of the world.

New countries, extensive parts of the world that were not even mentioned in the Bible, opened up before the astonished eyes of the people. And in these very years a new theory of the structure of the Universe appeared, proposed by Nicolaus Copernicus (1473-1543) who came from the Polish town of Toruń (Thorn). Copernicus was a canon, a member of the Church Council.

Nicolaus Copernicus (1473-1543)

How came it that a canon of the Church dared revolt against the Church's dogma on the creation of the world?

In the olden days those who served the Church formed a special estate or caste; they were known as the clerical estate and all other people belonged to the temporal or worldly estate. Education was given mainly to those who were preparing for a clerical calling. They learned to read because they had to conduct Church services according to the prayer-books. They were taught to write because future priests and bishops would have to correspond on Church affairs; before printing was invented monks copied the religious books by hand.

Among the people of worldly callings there were very few who could read and write. It was not infrequent that even kings and emperors only learned to scrawl their names and could neither read nor write: their business was also conducted by clericals.

Anybody who wanted to engage in science, therefore, had to be-

come a professional churchman. Nicolaus Copernicus, the son of a baker, did just that. He had been brought up by his uncle, a Catholic bishop, who even sent him to Italy to study for many years. In addition to theology Copernicus also studied medicine and technology and was a clever doctor and skilled engineer.

Copernicus was a great Polish patriot. Although he was a canon of the Church he took part in the wars against the Germans. As a skilled engineer he fortified castles and himself commanded the troops that defended them.

His duties in the Church took up considerable time and effort. He also devoted a great deal of his time to the healing of the poor sick people from whom he took no fees.

Evenings and nights, however, were free and Copernicus devoted them to the science he loved most of all, to astronomy.

Hundreds of years ago the astronomer's work was quite different from what it is today; an astronomer can now easily observe the heavenly bodies through powerful telescopes. Any part of the sky

This drawing of an astronomer's study was made in 1520

may be photographed and the pictures taken will show all the stars that are visible through a telescope and many that are not. In Copernicus' day there were no telescopes and the stars could only be studied with the unaided eye.

In order to carry out a scientific observation of the planets and stars the astronomer had to be able to determine their position in the sky in the same way as the position of a city is found on the map of the world. On the map of the sky the astronomers drew a network of lines, marked in degrees, that resemble the lines of longitude and latitude on your maps.

The instruments old-time astronomers used were very simple and were something like huge wooden protractors with two arms; one arm was fixed to the protractor and this was pointed towards the horizon, the other, movable arm, was pointed to the star. The angle between them showed the height of the star above the horizon. In those days there were not even clocks that measured minutes and seconds; people could only tell the time roughly by means of water and sand clocks.

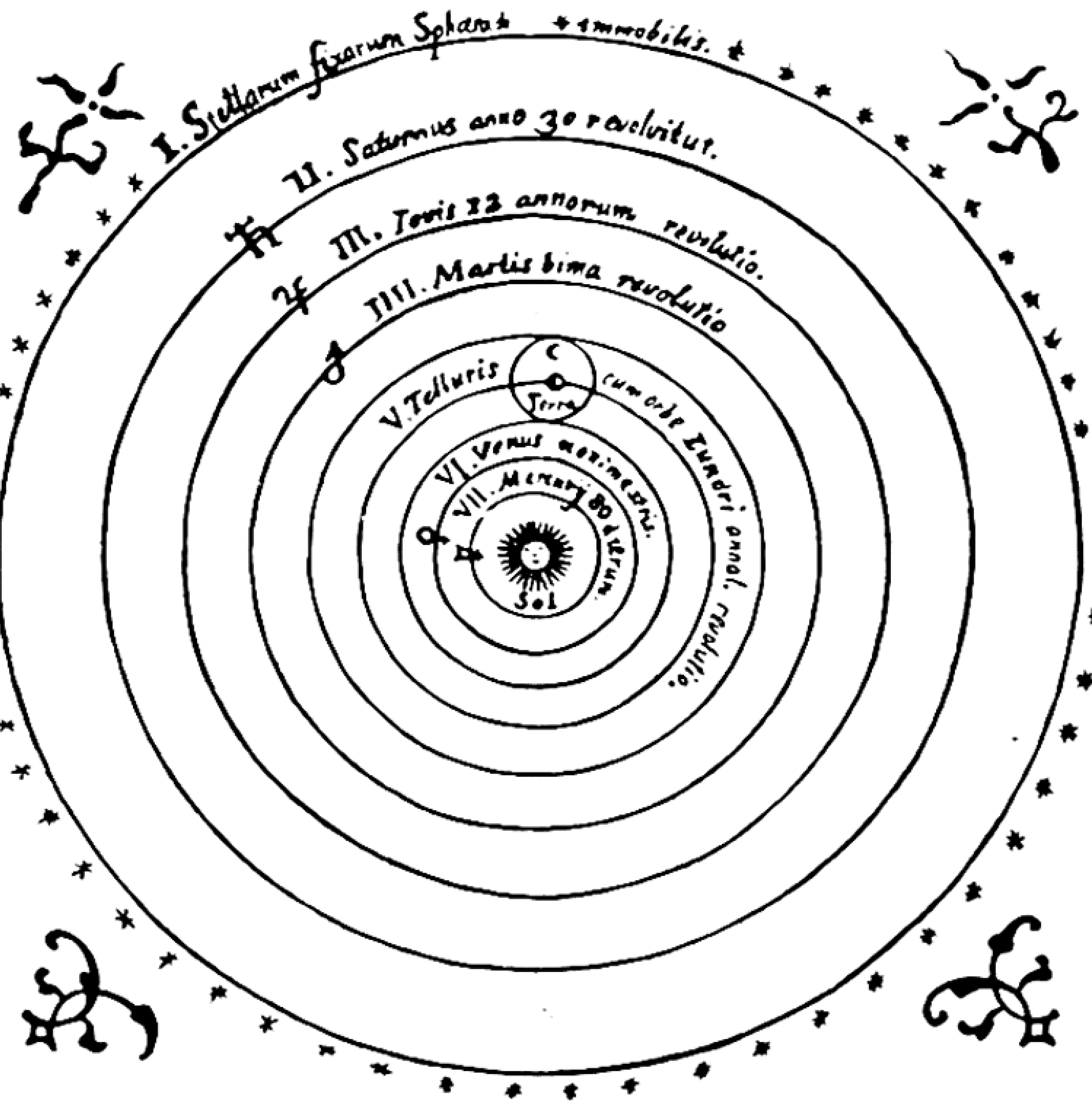
Infinite skill and patience, great love for science were needed to carry on difficult scientific observations with such imperfect instruments.

For years on end, night after night, in heat or in frosty weather, Copernicus went up to the roof of a turret on the wall surrounding the cathedral at Frombork (Frauenburg).

In the course of these long years of work Copernicus made countless observations of the stars and planets. These observations convinced him that the Ptolemaic system was erroneous. Copernicus found only one true statement in it—the Moon really does revolve round the Earth. Mercury, Venus, Mars and the other planets do not revolve round the Earth but round the Sun. And what about the Earth itself? Is it an exception, is it any different from the other planets? Of course it is not, like them, it also revolves round the Sun.

According to Copernicus the Earth could not be regarded as the fixed centre of the Universe for which all other heavenly bodies had been specially created.

Copernicus was quite right in asserting that the fixed stars had nothing to do with our solar system. He also guessed that the distance from the Earth to the Sun was a very small one compared



The Copernican system. The names of the planets are in Latin, the language in which all scientific works were written in those days

with the distance to the other stars. The revolution of the stars about the Earth is merely imaginary and is to be explained by the fact that the Earth rotates about its own axis once a day. This rotation of the Earth explains why the Sun and the planets appear to revolve around the Earth.

Copernicus made his great discovery when he was about forty years old. For many years after that he had to keep his discovery secret for fear of persecution and revealed it only to a few close friends.

Towards the end of his life Copernicus finally decided to allow his writings to be printed and then only because his friends persuaded

him to. Copernicus' book appeared in 1543. It is said that the first copy of the book was brought to Copernicus on his deathbed.

The Church authorities did not immediately realize the importance of the book. The great astronomer had written his book in such difficult language that the ignorant monks were unable to understand it.

For a long time there was no ban placed on Copernicus' book and people were able to study it unhindered. And so the new theory spread unnoticed through all Europe.

But when the Church Fathers at last discovered the real significance of this new system of the Universe they took up arms against Copernicus' theory; it undermined the very foundations of the Christian religion—the Bible taught that the Earth is the centre of the Universe, that man is the lord of the Earth and that the Sun, Moon and stars were created especially for man.

And then suddenly... the Earth is not the centre of the Universe but a tiny planet that moves round the Sun together with the other planets and even spins about its own axis like a boy's spinning top.

To this was added the information that Mercury, Venus and the other planets are not tiny spots of light on the crystal bowl of the sky but are also worlds with their own skies and nether regions. The astronomers at that time knew nothing about the nature of the other planets and believed that there was life on them as on our Earth. People living in the other worlds could not have descended from Adam and Eve, the first man and woman created by God, as the Bible said.

The Church Fathers were badly scared: it was enough for people to think about Copernicus' teachings and they would lose their faith; they would begin to understand the absurdity of the biblical legends and the Church would lose its power over the people.

GIORDANO BRUNO

In olden days it was difficult to get from Italy to Switzerland, for these two neighbouring countries are divided by high mountains, the Alps, and only dangerous, narrow paths ran through the high passes.

Rich people crossed the mountains on mules with local inhabitants to guide them. Poor people went on foot and sometimes lost their

way and were either frozen to death in the mountain snows or fell over some precipice. Deaths often occurred during the furious winter blizzards.

Travellers on mules and on foot formed large companies or caravans in order to defend themselves against the bands of robbers that infested the roads in those days and also the better to overcome natural difficulties.

Giordano Bruno
(1548-1600)

In the winter of 1576 one of the caravans setting out for Switzerland was joined by a young Italian wearing the garb of a monk.

At the inns where the caravan rested he kept apart from his fellow-travellers, remained seated in dark corners and did not take part in the general conversation; he gave brief answers to questions concerning the reason for his journey and when talking covered his face with the hood of his robe. On the road he kept to himself and it was noticed that he avoided meetings with the police or with other monks.

The curious did not guess the secret of the young Italian even at the end of the journey, but you will now hear his story.

The young monk's name was Giordano Bruno. He had fled from his native Italy because he was threatened with severe punishment for "free-thinking." Free-thinking meant that he had dared to think about many things in ways that differed from those ordered by the Church.

Giordano Bruno was born in 1548 in the little Italian town of Nola. He was left an orphan at an early age and was brought up in a monastery. You already know that in those days people who wanted to get an education had to apply to the priests and monks. All education was theological, religious, in character and the boys

learned to read from prayer-books and not from the A B C books that we have today.

The Catholic monks were divided into a large number of societies or orders, as they were called. The most powerful of them was the Dominican Order. Bruno was taught by the Dominicans. He was very clever, acquired much knowledge, was accepted into the Order and later ordained a priest.

Even while still young, Giordano pondered over the teachings of the Church and many things seemed incorrect to him, and the first timid doubts arose in his mind.

One day, on a remote shelf in the monastery library, he found a dusty leather-bound book that had been gnawed by mice. The young priest opened it and read the Latin title which told him that it was by Nicolaus Copernicus of Toruń and was about the revolutions of the heavenly bodies.

Giordano had already heard vague rumours of this famous book. And there it was, this great treasure, right in his hands! Giordano would learn about Copernicus' theory from the author himself and not from the lips of the monks.

Giordano Bruno studied the book in secret, in the quiet of the library that was seldom visited or behind the locked door of his own cell; he was astounded at the clarity and simplicity of the new system. He could not contain himself and immediately spoke to one of the monks of his admiration for the work of Copernicus; the monk reported Bruno's bold speech to the heads of the Dominican Order.

The young monk was threatened with severe punishment. It was then that he fled from his native land and renounced his office of priest. He kept to his monk's clothing because it was his best defence in a country where there were tens of thousands of monks and where they were respected and feared.

His flight took him to safety but Giordano Bruno did not see his native land again for many years. The rest of his life Bruno devoted to spreading Copernicus' ideas. He did not, however, merely repeat them like an industrious pupil—he developed the theories of Copernicus and his conception of the Universe was even more correct than that of his teacher.

Giordano Bruno said that not only the Earth but also the Sun rotates about its axis. This was proved correct many decades after Bruno's death.

He also asserted that there are many planets revolving round our Sun and that new ones, still unknown to the world, would be discovered. The first new planet, Uranus, was discovered two hundred years after Bruno's death and at an even later date Neptune, Pluto and hundreds of tiny planets—the asteroids—were discovered. Thus the prophecy of a man of genius came true.

Copernicus had paid little attention to the distant stars. Bruno maintained that every star was a Sun as big as our own and that it had planets revolving round it; we could not see them, he said, only because they were too far away. Every star is the centre of a Universe like our solar system and there is an infinite number of these Universes in space.

Giordano Bruno also maintained that all these systems that exist in space have their beginning and their end and that they are constantly changing. This was an unusually bold idea; the Christian religion taught that the Universe is imperishable and that it has always existed in the form in which God created it.

Bruno possessed an amazingly keen mind; by exercise of his intellect alone he understood things that astronomers later discovered with the help of telescopes. It is difficult for us today even to imagine what a tremendous change Giordano Bruno brought to astronomy. It was as though he had released a prisoner from jail and the former captive saw the marvellous and endless Universe in place of the walls of his dark and narrow cell.

The astronomer Kepler, who lived somewhat later, admitted that he "felt dizzy when reading the writings of the famous Italian and that a furtive horror seized him at the idea that he was probably wandering through space, space that had no centre, no beginning and no end. . . ."

The Church came to regard Giordano Bruno as its most dangerous enemy. Bruno's theory that there exist countless inhabited worlds, that the Universe is endless, completely refuted the biblical stories of the creation of the world and Christ's advent on Earth upon which the Christian religion is based. The accusation put forward by the Church against Giordano Bruno contained a hundred and thirty points.

The Church Fathers declared Bruno to be a blasphemer and persuaded the authorities to forbid him to live first in one country, then in another. The more Bruno was forced to wander the more he spread his teachings throughout the world.

Bruno lived long in exile and longed to return to his sunny Italy. The astronomer's enemies made use of this to ruin him.

A young Italian aristocrat, Giovanni Mocenigo, pretended to be interested in Bruno's numerous writings that had been printed in various European cities.* He wrote to Bruno saying that he wanted to become his pupil and that he would reward him generously for his labour.

It was very dangerous for the exile to return to his native land but Mocenigo treacherously assured him that he would be able to protect his teacher from all enemies. Bruno believed him, especially as he had grown tired of wandering in foreign countries.

The great scientist did not know that the treacherous plan to lure him back to Italy was the work of the Inquisition, the dread court held in Italy and Spain for the persecution of those accused of crimes against religion. The inquisitors, or judges, brought about the death of hundreds of thousands of victims; Bruno was one of them.

Giordano Bruno went to the city of Venice and began giving lessons to Mocenigo. His pupil made him promise that if he intended to go away he would first come to bid him farewell. This was a cunning scheme: Mocenigo was afraid that Bruno would get to know of the plans of the Inquisition and would take flight as he had done in his youth. If the astronomer came to bid him farewell he would be able to hold him back.

After studying for a few months Mocenigo said that Bruno was making a poor attempt at teaching him and did not want to let him share all his secret knowledge.

In response to this Bruno made ready to quit Venice and Mocenigo gave information against him to the Inquisition. On May 23, 1592, the famous scholar was arrested and spent eight terrible years in prison.

The cell in which he was held captive was directly under a lead roof; in summer it was unbearably hot under such a roof and in winter it was damp and cold. The captive's life in this prison was one long torment—it amounted to slow death.

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* The biggest existing collection of the first editions of Bruno's writings is that of the Lenin Library in Moscow.—*Ed.*

Why did his executioners keep Giordano Bruno in prison for eight years? They hoped to force the astronomer to renounce his teachings. If he had done so it would have been a great triumph for them. Bruno was known and respected all over Europe and if he had announced that he had been mistaken and that the Church was right there were many people who would have again believed the Church legend concerning the structure of the Universe.

Giordano Bruno, however, was a man of firm courage. The threats and tortures of the church inquisitors could not break him: he stubbornly offered proofs of the truth of his teachings.

The Inquisition sentenced him to death. When he heard the decision of the court Giordano Bruno said to the inquisitors in a calm voice:

"The fear you experience in pronouncing your sentence in the name of a merciful God is greater than mine in hearing it."

The Inquisition was in the habit of pronouncing its hypocritical sentence in the following words: "The Holy Church asks that the guilty person be punished without blood being spilled." This was actually the most terrible of all sentences—it meant that the victim would be burned alive!

Giordano Bruno was burned at the stake in Rome on February 17, 1600.

The condemned man was led to his execution with great solemnity. Before him went a banner the colour of blood. The bells of all churches were rung. Hundreds of priests in full ceremonial attire sang funeral hymns. The condemned man was dressed in a yellow robe on which ugly figures of the devil had been painted in black. A high conical cap had been placed on his head and on the cap there was a drawing of a man squirming among the flames of a fire. The heavy fetters on his hands and legs rattled as he walked. The executioners were afraid that the fearless Bruno would make a last attempt to tell the people the truth and had slit his tongue so that he could not speak.

The condemned Bruno was followed by a procession of bishops and priests, state officials and aristocrats, all in rich attire.

Hundreds of thousands of Roman citizens were gathered on the square where the execution was to take place; the streets along which the procession passed were also packed with people. The crowd, hungry for entertainment, regarded the whole proceedings

as a holiday spectacle and there were but few people who were shocked at the terribly brutal treatment of the courageous scholar.

Before he was tied to the stake Giordano Bruno was again given an opportunity to renounce his theories in return for a pardon. The great astronomer contemptuously refused the offer and went to the stake with a firm step. Not a groan came from his lips as the flames of the fire enveloped him.

The great astronomer had died at the stake but the Church authorities were unable to prevent the development of science.

Every soldier of science killed in the struggle was replaced by ten others.

In 1889 a monument to Giordano Bruno was erected on the square in Rome on which he met his death.

Giordano Bruno is burned at the stake

GALILEO GALILEI AND HIS MARVELLOUS DISCOVERIES

The year Giordano Bruno was executed Galileo Galilei reached the age of thirty-six. He believed that the Copernican system was correct but he was appalled by the terrible fate of Bruno and would not take the risk of coming out directly in defence of the system.

It was just at this time that an important event occurred: the telescope was invented. Galileo was the first man to point the new instrument to the stars. What the Italian astronomer saw in the sky was a positive proof that the Copernican system was a true one. On the moon Galileo saw mountains and plains; the Moon proved to be an extensive world in many ways resembling our Earth.

Galileo saw the planet Venus in the form of a crescent, like that of the Moon, and not merely as a bright point in the sky.

The most interesting of all was the observation of the planet Jupiter which Galileo began on January 7, 1610. The telescope showed the astronomer that Jupiter was not a tiny spot of light but a fairly large circle. There were three little dots to be seen in the vicinity of the circle and on January 13 Galileo discovered a fourth.

If you look at the illustration on page 52 you will probably wonder why Galileo did not notice all four points of light immediately—they photograph so well! But we must remember that Galileo's telescope was very weak and the best of those he afterwards made himself had a magnification of only 30 diameters. Galileo discovered that all four points of light not only followed Jupiter as it moved through the sky, they also revolved around that huge planet. In this way it was discovered at once that Jupiter had four moons.

Galileo Galilei
(1564-1642)

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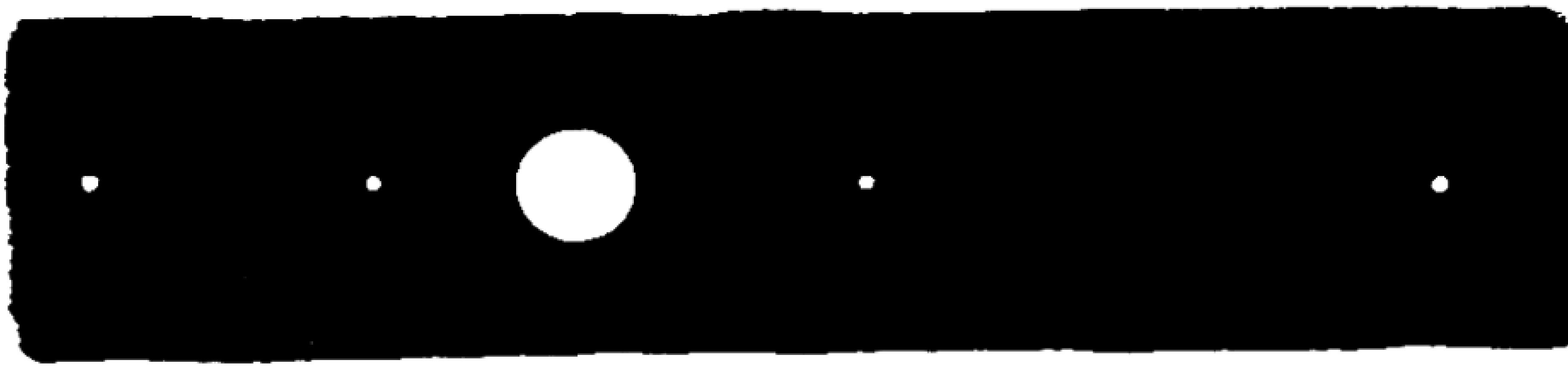


This is what Galileo saw when he pointed his telescope towards Jupiter

Galileo's discovery was treated with contempt by the world of science. Professor Cremonini of Padua University refused to look through a telescope:

"Why should I look through a telescope when I know that Jupiter has no satellites and cannot have any!"

With this foolish statement Cremonini made his name "famous."

Other astronomers said that Jupiter should not have any satellites because they were of no use to man.

One bishop said:

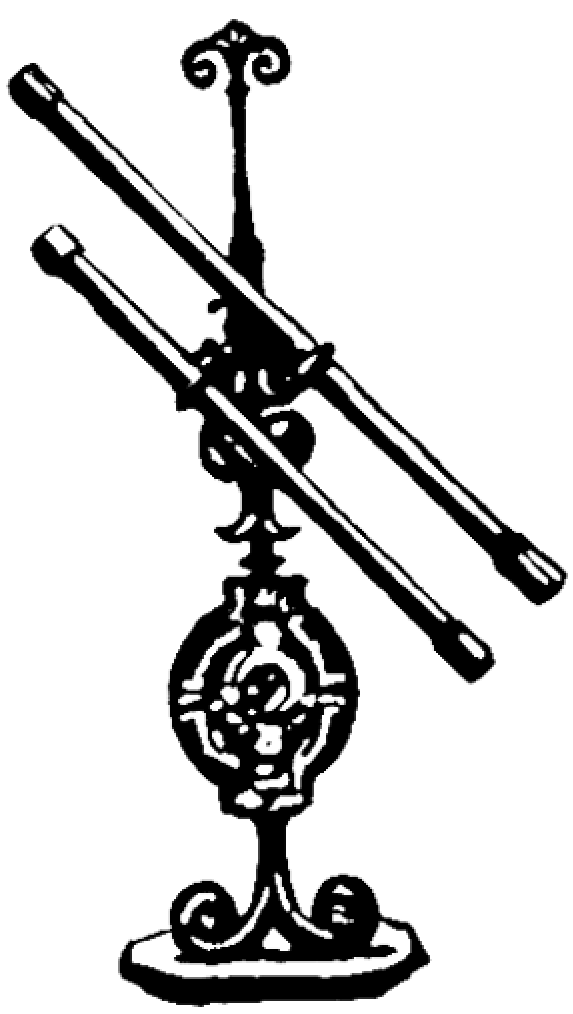
"There are seven days in the week; in man's head there are seven openings—two eyes, two ears, two nostrils and a mouth; in the sky there are seven planets—the Moon, Mars, Jupiter, Mercury, Venus, the Sun and Saturn. If it be admitted that Galileo has discovered four more planets there will be eleven and this is not possible!"

He, too, refused to look through the telescope.

Despite all their objections the astronomers eventually had to admit that Jupiter's satellites really did exist.

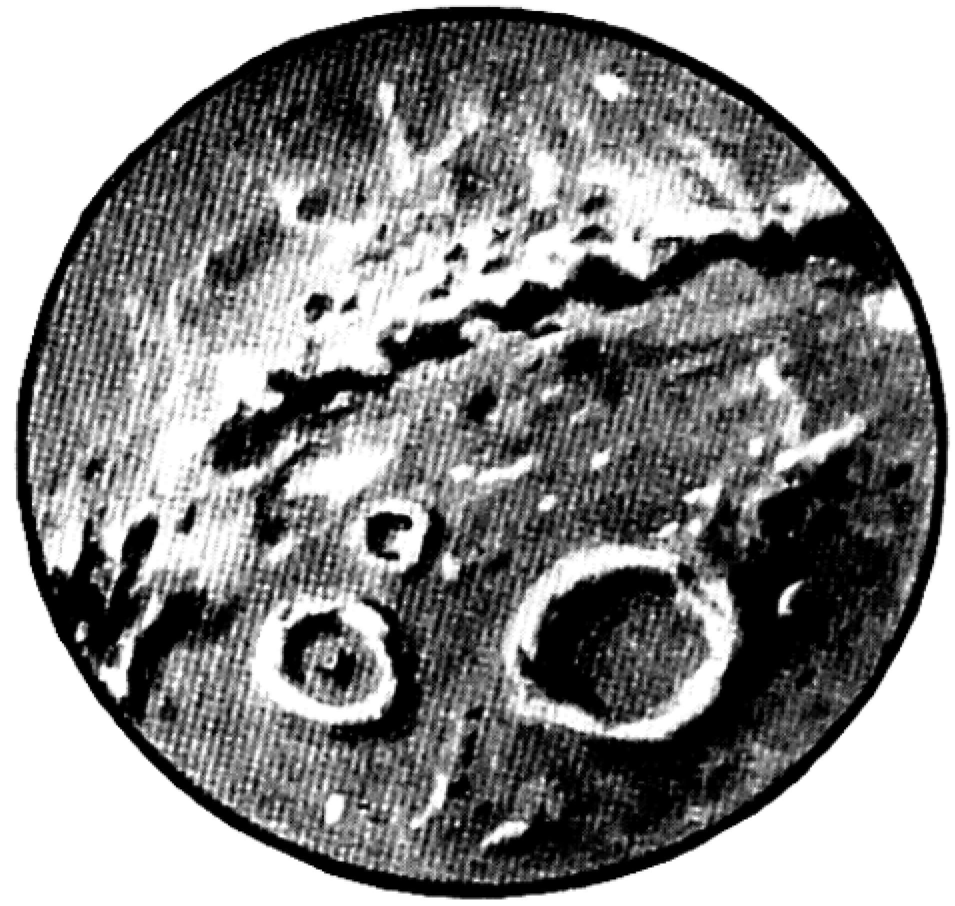
The easiest of the heavenly bodies to observe is the Moon. On any moonlit night our companion of the skies can be studied through the weakest telescope and such observations afford man considerable pleasure.

"Come and look!" Galileo said to all those who doubted his discoveries.



Galileo's telescope

The astronomer realized that the best way to make real knowledge of the sky widely known was to get as many people as possible to make observations. Every night numbers of people gathered around Galileo—friends, acquaintances and even people quite unknown to him—and all of them wanted to look at the Moon with their own eyes. And what an impression these observations created on those who saw them!



The surface of the Moon through a telescope

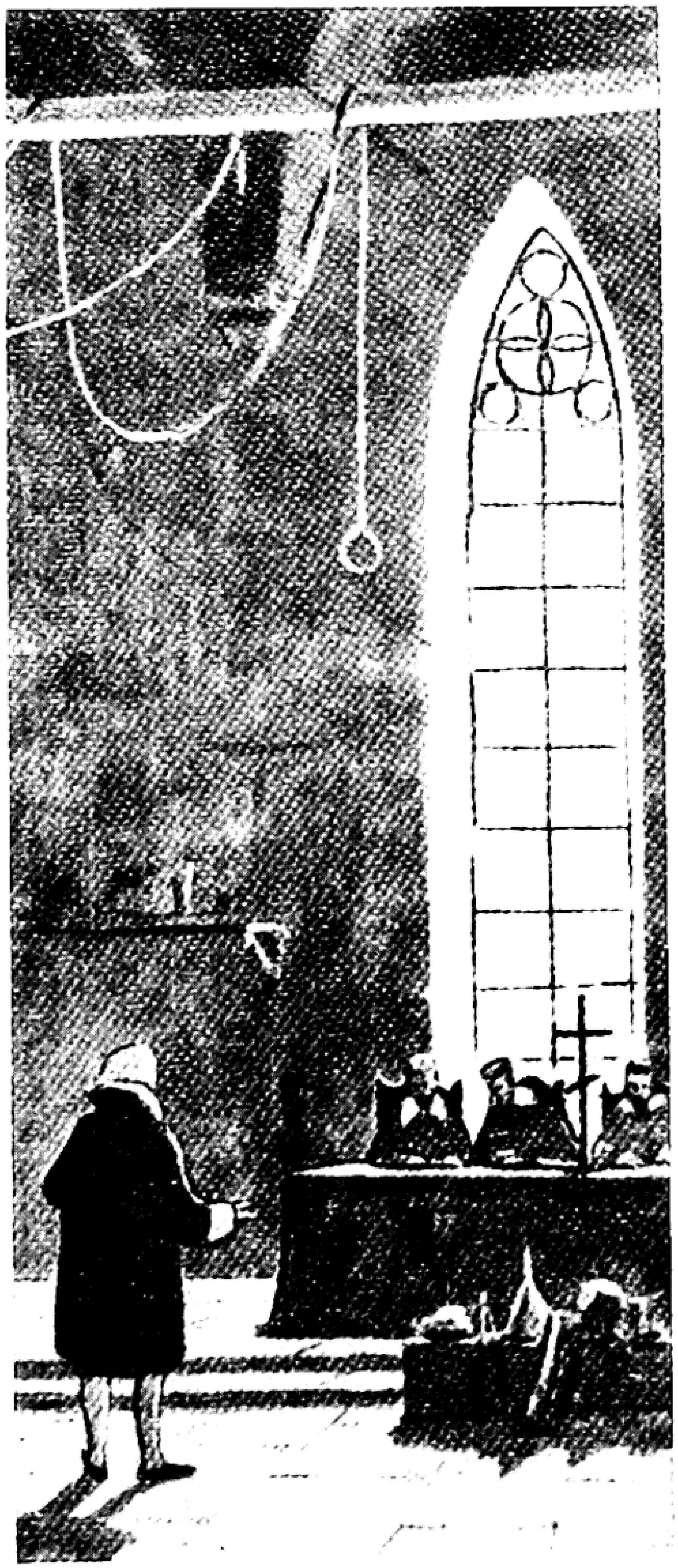
On the surface of the Moon they saw huge dark patches that Galileo mistakenly believed to be seas and oceans. They saw long ranges of mountains whose height Galileo learned to estimate by the lengths of their shadows. By that time it had already become ridiculous to say that the Moon was a silver dish fixed to the firmament and that it had been created to give light to the Earth.

After making such wonderful discoveries Galileo could no longer remain silent. The Copernican system was still not openly forbidden by the Catholic Church and in 1610 Galileo wrote a book with the wonderful title *Sidereus Nuncius* or *Herald of the Stars*. In his book Galileo spoke in favour of the Copernican system, but he did so with great caution.

The Church Fathers were worried: although they had killed Bruno the teaching of Copernicus had not perished with him, a new defender of the system had appeared to spread it among the people.

This defender and popularizer was a scholar whose name was known to the whole of Europe.

The Pope of Rome, head of the Catholic Church, issued a decree. This decree said that the most severe punishment would be inflicted


Galileo before the Inquisition

on anybody who printed books supporting the Copernican system. It was, furthermore, considered a crime even to possess such books and read them.

The Church had so great a hatred of Copernicus' teachings that writings supporting it were strictly forbidden until 1835.

The Church Fathers then attacked Galileo himself. In 1632 he wrote a book called *A Dialogue on the Two World Systems* in which he again supported the Copernican system. Galileo had great difficulty in getting this book printed. Printers refused to accept his order: they were afraid that they would be persecuted as confederates in spreading the Copernican "heresy." Nevertheless the book was published and the Church Fathers were furious.

It was forbidden to distribute Galileo's book and the aged astronomer was ordered to go to Rome to be judged by the Pope himself.

Galileo was threatened with death, he was questioned in the torture chamber where, before his eyes, were the terrible instruments—leather funnels through which huge quantities of

water were poured into the stomach, iron boots that could be screwed up to squeeze the foot, pincers for breaking the bones. . . .

The decrepit old man could not stand up to the threats and renounced his own writings.

On June 22 he made public his repentance, kneeling in church in the presence of a great crowd.

Even after this the Church did not let the old astronomer slip out of their grip. Galileo was a prisoner of the Inquisition until his death. He was strictly forbidden to speak to anybody about the motion of the Earth. Nevertheless, Galileo worked secretly on a new book in which he affirmed the truth about the Earth and the heavenly bodies.

Neither persecution, torture nor executions could prevent the spread of the new teachings. The heroes and martyrs of science had done their great work.

TELESCOPES AND OBSERVATORIES

The first and most important tool of the astronomer's trade is the telescope. The invention of the telescope played such a tremendous role in the advancement of science that we must say at least a few words about its history.

Some people have poor sight, they may be either near-sighted or far-sighted. A near-sighted person sees objects that are close to him but cannot properly distinguish those that are farther away. Far-sighted people see distant things clearly but cannot see to thread a needle or distinguish the letters in a book.

Long, long ago people learnt to remedy defective vision by means of eyeglasses. The lenses of eyeglasses may be convex (bulging outwards) or concave (bulging inwards).

Double-convex lenses have a bulge on each side and the centre is thicker than the edges. This is the shape of a burning glass. If you look at the letters in a book through a double-convex lens they will appear much bigger; for this reason such a lens is called a magnifying glass.

The double-concave lens is the opposite—it is thinner in the middle than at the edges. This is a reducing glass and things seen through it appear smaller.

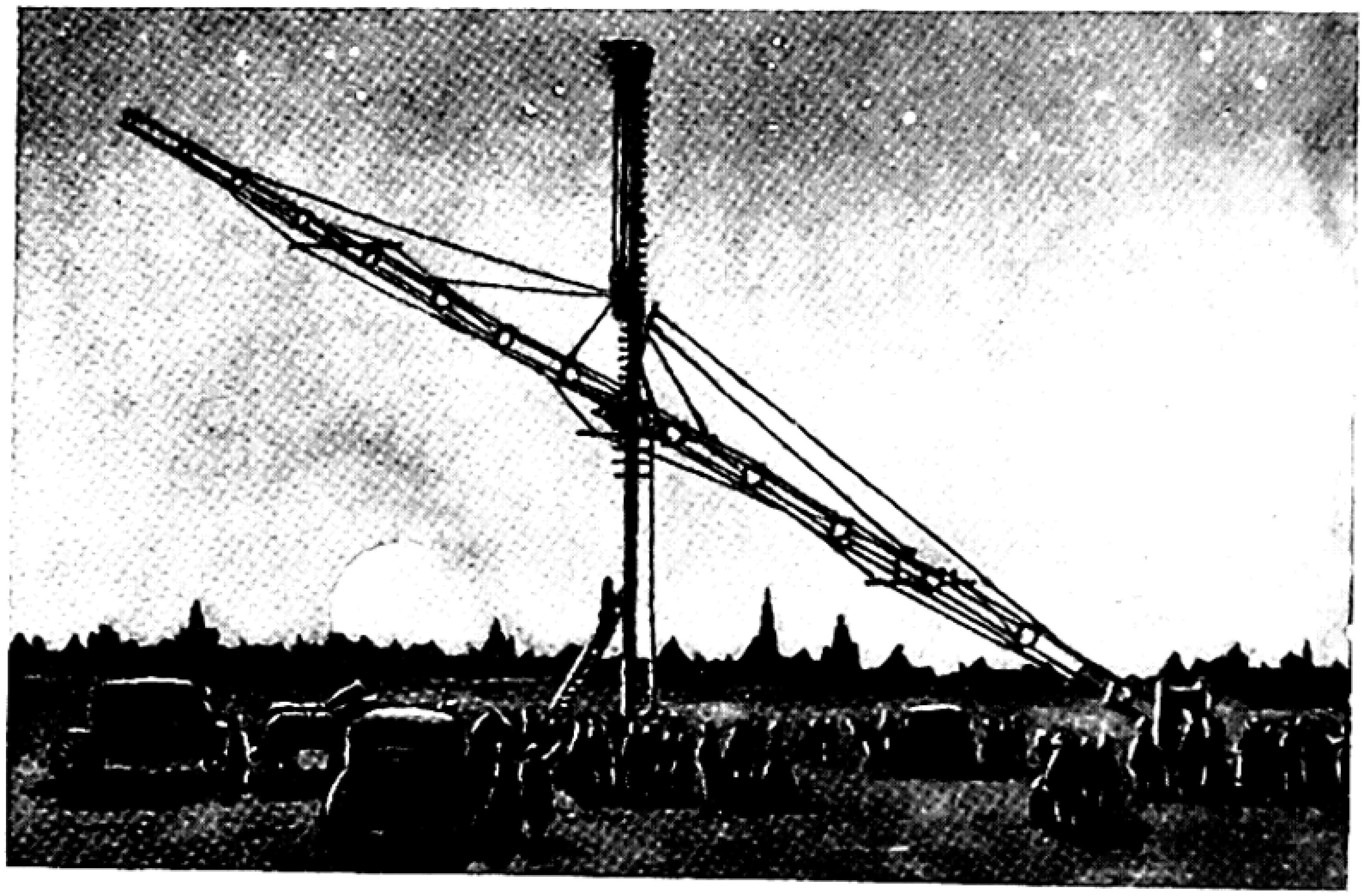
The story is told of an accidental discovery made about three hundred and fifty years ago. A small boy, the son of a craftsman making eyeglasses, was playing with a double-convex and double-concave lens. He held them in front of his eyes this way and that and accidentally placed one lens in front of the other—a distant belfry suddenly seemed to come quite close to him. The boy told his father and the craftsman placed the two lenses in a tube and in this way is supposed to have invented the first telescope.

It does not matter whether this story is true or not. The important thing is that about the year 1605 the first telescope made its appearance in Europe. It was made of a single tube (and not two like present-day field or opera glasses) and the observer had to look through it with one eye and keep the other eye closed.

You already know that Galileo made some wonderful discoveries by using a telescope, but his instrument was very far from perfect.

Clever craftsmen began to improve the telescope and to build bigger ones. The first small ones were called spy-glasses and the name of telescope was first given to big instruments. Telescope is a Greek word that means "seeing at a distance," and it was given this name because it helps you see things that are far away.

The first big telescopes were very inconvenient to use. On page 57 there is a picture of the big telescope built by Jan Heweljusz (Hevelius) in the Polish town of Gdansk. As you see, this telescope did not even have a tube. It was raised and lowered by ropes and was very difficult to use.



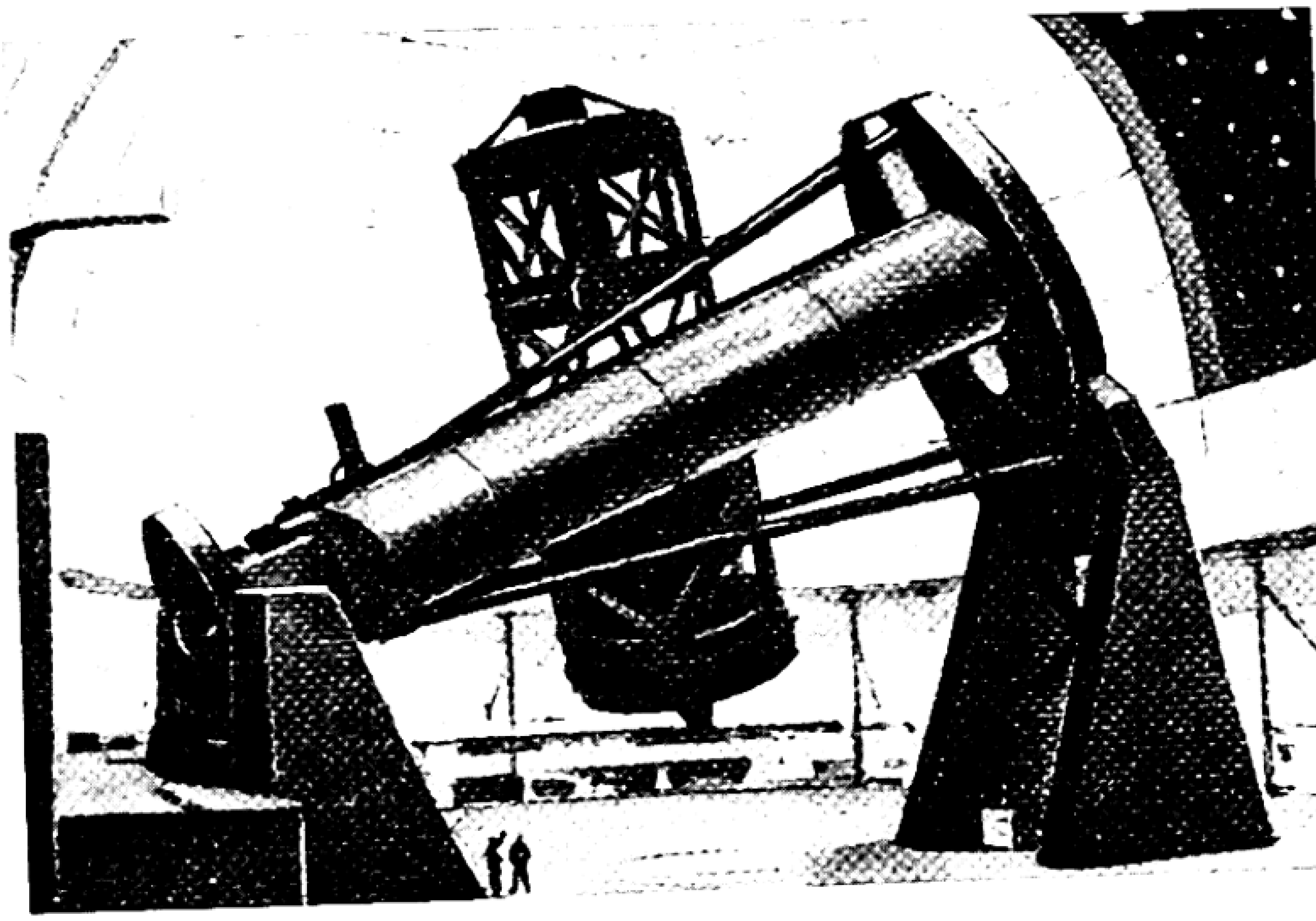
Hevelius' giant telescope

Very soon the reflecting telescope was invented. This instrument has a highly polished concave mirror in its main part and its body resembles a huge cannon pointed at the sky.

In 1941 the Soviet scientist D. D. Maksutov invented a more perfect telescope of an entirely new type. The chief part of Maksutov's telescope is a concave mirror and a lens that is concave on one side and convex on the other. If you cut through such a lens it has a cross-section shaped like the crescent moon, or *meniscus*; this is the Latin name scientists gave to the new telescope, the meniscus telescope.

The meniscus telescope gives a good image and its body or tube is much shorter than the older types of telescope; this makes it much easier to use. Very simple telescopes, easy to use but showing good pictures of the sky are now being made.

The observation of the heavenly bodies is carried out in observatories that are usually built well away from big cities, on hills or even on high mountains, where there are fewer clouds and where



A five-metre reflecting telescope

the air is more transparent and calmer; higher up, the air does not quiver as it does on low-lying plains.

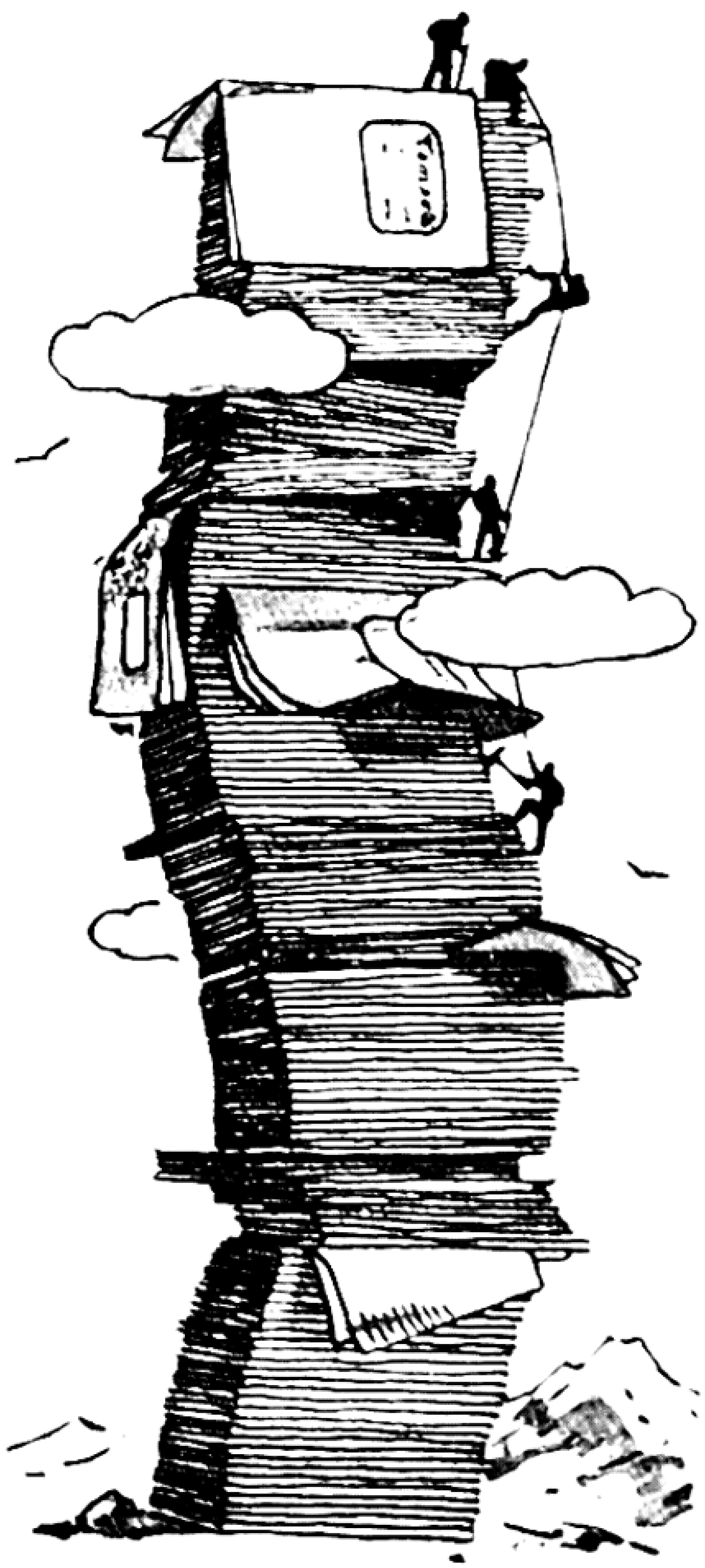
One of the best observatories in the world is that on Pulkovo Hills, near Leningrad; it has become famous for the discoveries made there and for the accuracy of its observations. Foreign astronomers have called Pulkovo "the astronomic capital of the world." The well-known American astronomer Newcombe once said that one Russian observation made at Pulkovo was worth four British observations made at Greenwich (near London).

The Nazi invaders destroyed the Pulkovo Observatory during the Great Patriotic War but it has since been rebuilt.

HOW BIG IS THE EARTH?

In this book you will often meet with big numbers like millions and thousands of millions. You know, of course, that a million is a thousand thousands but this is not enough—you must try to realize just how big this number is.

One scientist suggested the following method: if you want to know just what a million looks like take a hundred big sheets of paper and make ten thousand dots on each of them (one hundred lines of a hundred dots each). Hang all these sheets of paper on the walls of a big room and as you turn round you will see a million dots. Perhaps you would like to try it? If you would, I must warn you that even if you make three dots a second and keep on without stopping, the work will take you 92 hours.



Such a job is too big for any boy or girl to do but if the whole class sets about it, it will not take more than about two hours; the sheets of paper can then be hung on the class-room walls.

In this way the whole class will get a good idea of just how big a million is.

Now imagine that the factory that makes your school exercise books were to order a million of them to be piled up one on top of the other. How high do you think the pile would be? Certainly not less than 1,500 metres! It would make a good mountain for young mountain-climbers to train on. Now imagine a million ordinary pencils laid out end to end—the length would be 180 kilometres. And if the pencil factory were to make one big pencil out of the material of a million it would be 18 metres long and would weigh seven tons. Only the giant in the fairy tales, the big man with his head in the clouds, could write with such a pencil.

Now let us try to imagine a

thousand million (the Americans call this a billion but in other English-speaking countries a billion is a million million).

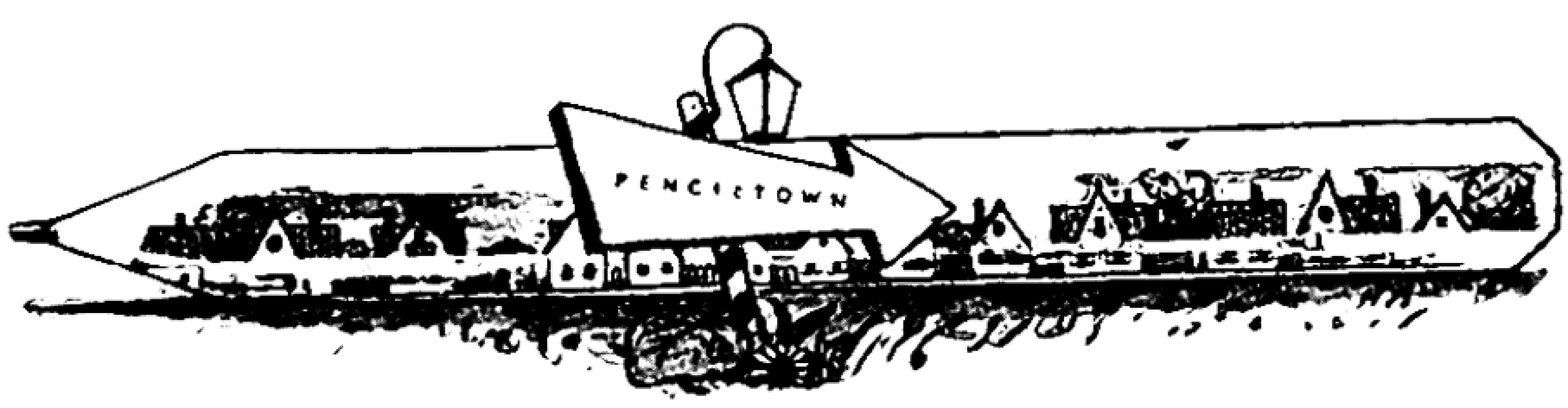
If we increase the size of even small objects that surround us by a thousand million they would become really gigantic. A pile of a thousand million exercise books would be 1,500 kilometres high! Its summit would be outside the Earth's atmosphere and could only be reached by a rocket.

If fifty pupils were to count exercise books for six hours a day without any holidays and each of them could count 3,000 books an hour it would take them over three years to count up to a thousand million.

A thousand million pencils laid end to end would go more than four times round the Earth. And if the material of a thousand million pencils were made into one big pencil it would be 180 metres long, six and a half metres thick and would weigh 7,000 tons. If that big pencil were hollow, like a pipe, you could build about fifteen one-storey houses in it and about a hundred people could live there.

"We live in Penciltown," they would say with pride.

And now let us get back to the size of the Earth.



If anybody thought of digging a well to the centre of the Earth it would have to be 6,380 kilometres deep. If a man went down a staircase or a ladder into the well at the rate of five kilometres an hour he would have to keep walking for nearly two months without stopping day or night.

Of course it would be quite impossible to dig such a well; the deepest mines are not much more than two kilometres deep and that is only about one three-thousandth of the distance from the surface of the Earth to its centre.

What is there inside the Earth under its hard crust? This is a question that is still difficult to answer. The surface of the Earth, on the other hand, has been studied very thoroughly and there are few places left that have not been visited by travellers.

The Earth measures about 500 million square kilometres. A square kilometre is a measure of area. It is a square with sides a kilometre long, and is equal to 100 hectares. The Earth's surface, therefore, has an area of 50,000 million hectares.

About seven-tenths of this surface is covered with water, the seas and oceans, and only about three-tenths of it is land.

How great is the volume of the Earth?

Can you imagine a cubic kilometre? If you imagine it as a box it would be a kilometre high, a kilometre wide and a kilometre long. All the houses and other buildings of the big city of Moscow could be packed into that box. The volume of the Earth is more than a million million such cubic kilometres!

It is very difficult to imagine the Earth's mass, that is, the amount of material of which it is made. So I'll try to give you a picture of it.

Suppose people decided to move the Earth to another part of the Universe. If they were to load the Earth's mass, all the matter of which it is made—stone and metals, water in big barrels, gas compressed in cylinders—into railway trucks carrying 100 tons each, how many trucks would there be in the train that carried the Earth?

If I were to name the huge figure you would not know the word so I will put it another way: when the last truck was just leaving the place where the Earth is now the engine would have reached the region of the distant stars.

The fastest thing in the Universe is the speed or velocity of light. It travels 300,000 kilometres a second.

If you say, "Goodness! How fast that is!" a ray of light will have travelled eight times round the Earth while you were saying it.

And if you say "How far to the Moon!" a ray of light will have travelled that distance before you finished saying it.

The guard at the end of the train carrying the Earth lifts his lantern to give a signal to the engine driver. How long will it take the light to reach the driver? It would take more than 60,000 years. And that's how great the Earth's mass is!

There have to be guards on our Earth train. There are a lot of trucks but it has been decided to have only one guard for every twenty thousand million trucks. Even so it would require the entire population of the Earth, about 2,500 million people, to make up the crew of that amazing train. Every guard would be 360 million kilometres away from his nearest neighbour and that is almost two and a half times the distance from the Earth to the Sun. If one of the guards decided to visit his neighbour and walked along the roofs of the trucks at the usual walking speed, five kilometres an hour, it would take him 6,900 years to do it.

In some of the capitalist countries there are scientists who maintain that there are too many people on Earth and that the Earth will soon be unable to feed all the people living on it.

This is obviously not true!

If the surface of the Earth were to be divided up evenly among the entire population, every man, woman and child would receive five hectares of dry land and 12 hectares of water. And how much grain, fruit and vegetables can you grow on five hectares! Hundreds of people could be fed from the amount of land allotted to each person.

Of course, a lot of work would have to be done to make the deserts of sand and the deserts of ice and snow fit to grow things on, but man is quite capable of doing it.

Some scientists also say that there will soon be a shortage of coal, iron and oil. This is also untrue.

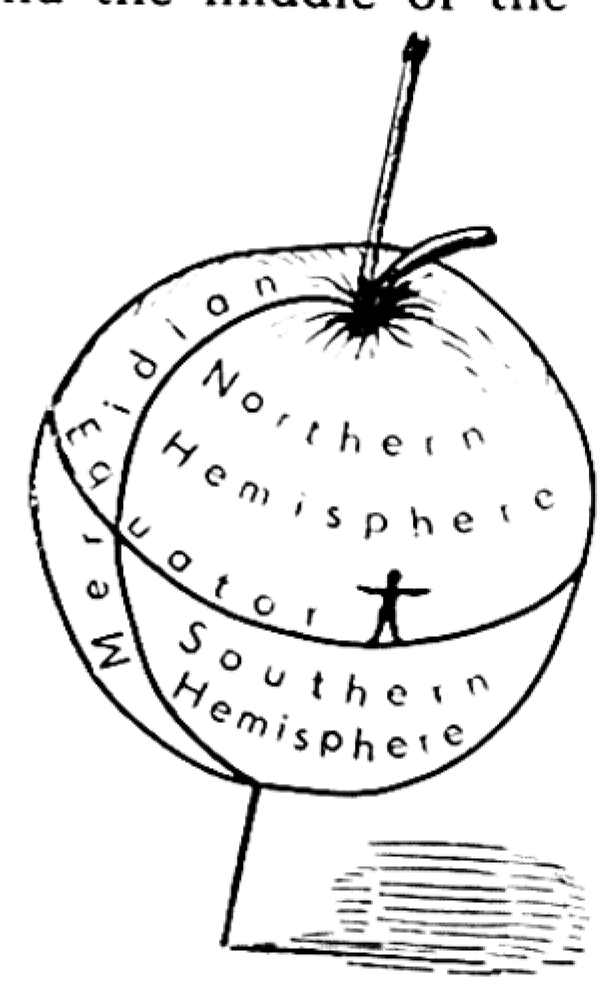
The riches of the Earth will never run out. Today the power of the rivers, the force of the wind, the heat of the Sun's rays and atomic energy are all beginning to take the place of coal and oil.

There are inexhaustible supplies of metals in the Earth, but if any one of them does run short engineers will be able to substitute another metal or a plastic for it.

POINTS OF THE COMPASS

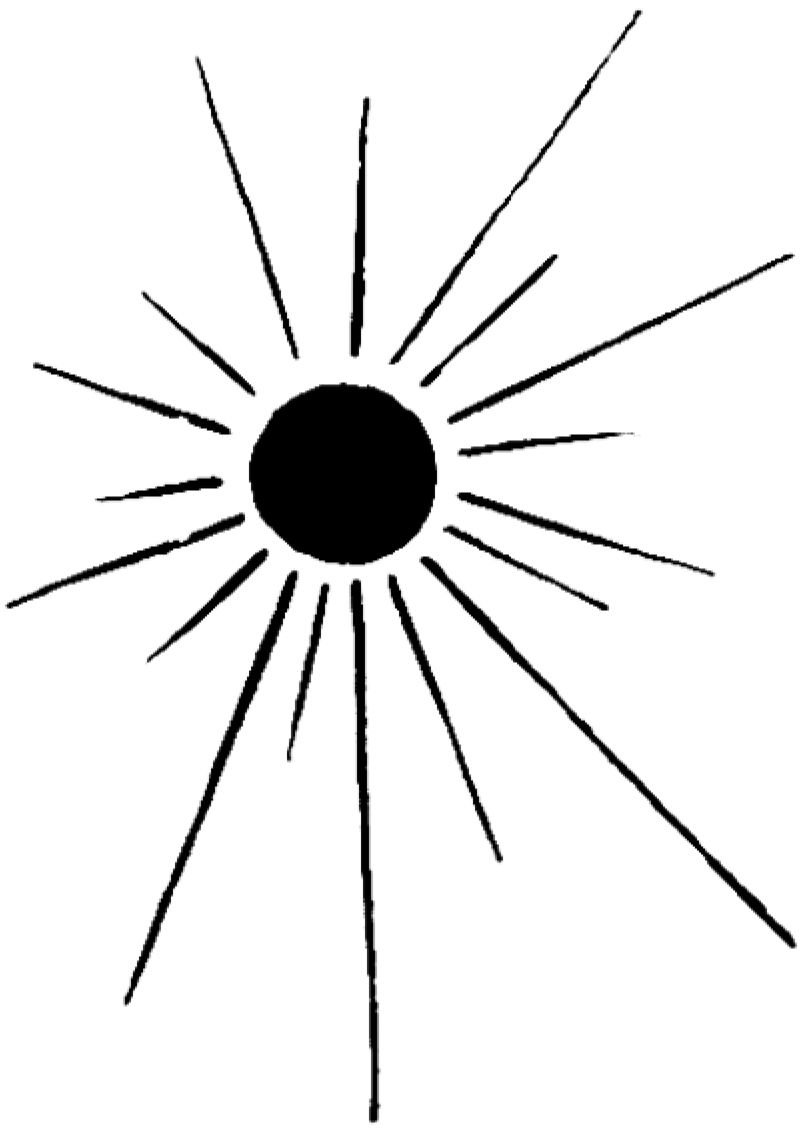
Take a thin knitting-needle and stick it into an apple so that it passes through the centre. The easiest way is to stick it in where the stalk is. In this way you make the knitting-needle the axis of the apple and you can spin the apple round on it in the same way as a wheel turns on its axle; the apple moves but the axis remains still.

The points where the needle enters and leaves the apple are the poles, the north and south poles. Let us call the point where the stalk grows the north pole. In this way you can easily distinguish one pole from the other. Now draw a line round the middle of the apple so that it is the same distance from each pole; this line is the equator and it divides the apple into two halves or hemispheres. The hemisphere on which we have our north pole will be the northern hemisphere and the other will be the southern.



Make a little man out of cardboard and place him on the equator looking towards the north pole or, to put it more simply, looking towards the north. The man's right hand will point to the east and his left hand to the west.

Then draw a line from the north pole to the south. This line is called a meridian, a word that means the midday line. How did it get this name? It is easy to tie a thread round an

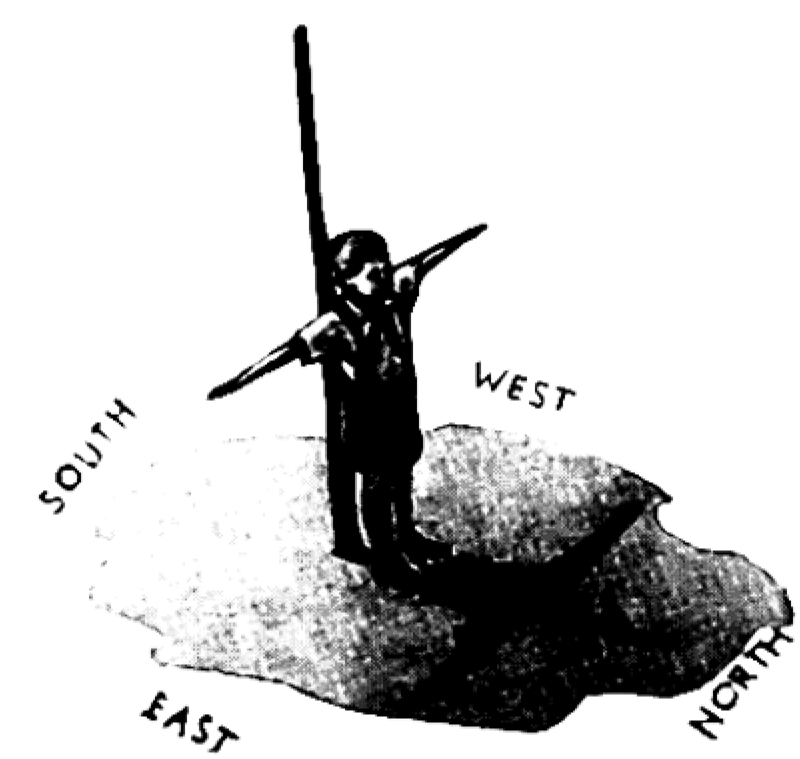


apple from the north to the south pole but it cannot be done on the Earth; you would need a thread 20,000 kilometres long and you would have to carry it over huge mountains, seas and deserts. You can, however, draw a very small piece of a meridian and here is how you do it.

Take a long pole and stick it into the ground so that it stands perfectly upright. Then you have to choose a sunny day and watch the shadow of the pole move. Early in the morning it will be long and, as the sun rises, will get shorter and shorter. It is shortest at midday, or noon, and then begins to grow longer again.

You must choose the moment when the shadow is shortest and drive a peg into the ground; a line drawn from the peg to the pole will be part of a meridian and if you live in the northern hemisphere the pole will be the southern end and the peg the northern end of your line. The line you have drawn is called the meridian or midday line because it is drawn at noon.

If you stand with your back to the pole and your face towards the peg you will be looking towards the north, south will be behind you, east on your right hand and west on your left. This is the way to find the four main points of the compass. There are also other points in between them—north-east between north and east, north-west between north and west, south-east between south and east and south-west between south and west.



How to find the points of the compass

Travellers on land and sea who have to be more accurate in their direction, put a lot more points between these, such as north-north-east, east-north-east, and so on. I think that by now you will easily understand the meanings of these **terms.**

But how are these directions to be found on a cloudy or rainy day? In such weather you have to use the magnetic needle of the compass one end of which points north and the other south. The little round card of the compass has all the points marked on it; that is why they are called the points of the compass.

On a clear night you can find north, south, east and west without a compass by looking for the Pole Star.

The Great Bear and the Pole Star

There is a constellation or group of stars that all the peoples living in the northern hemisphere know—it is called the Great Bear, or Ursa Major. It is true, the constellation does not look anything like a bear but more like a pot with a handle; people in the olden days called it the Big Dipper and this is probably the most suitable name for it.

If you imagine a line drawn through the last two stars of the Dipper and continue it across the sky about five times farther it will almost pass through the Pole or North Star.

The Pole Star never changes its place in the sky, all the other stars revolve round it as though it were the centre but the Pole Star is always in its place.

The Pole Star shows you the north and you only have to stand facing it to find the other points of the compass.

The Pole Star is the end star in another constellation, the Little Bear, or Ursa Minor, that is shaped very much like the Great Bear.

The Kazakh people had interesting names for the Great and Little Bears. The Kazakhs were formerly a pastoral people who lived by raising sheep, camels and horses. And they thought that there were also herdsmen in the sky. The motionless Pole Star they called the stake to which six horses, the other stars of the Little Bear, were tied. All night long they wander round the stake and eat the heavenly grass. The seven stars of the Great Bear that wander all night round the stake and the horses they called the seven horse-thieves who were trying to steal heavenly horses.

Learn to find the Pole Star in the sky, later on it will be useful to know.

WHAT CAUSES DAY AND NIGHT ON THE EARTH

When you are in a train moving slowly out of a station it seems to you that a train standing still on the next line is moving backwards. Actually it is your train moving slowly forward. The illusion disappears as soon as your train gathers speed and begins to bang on the rails and to sway and rattle.

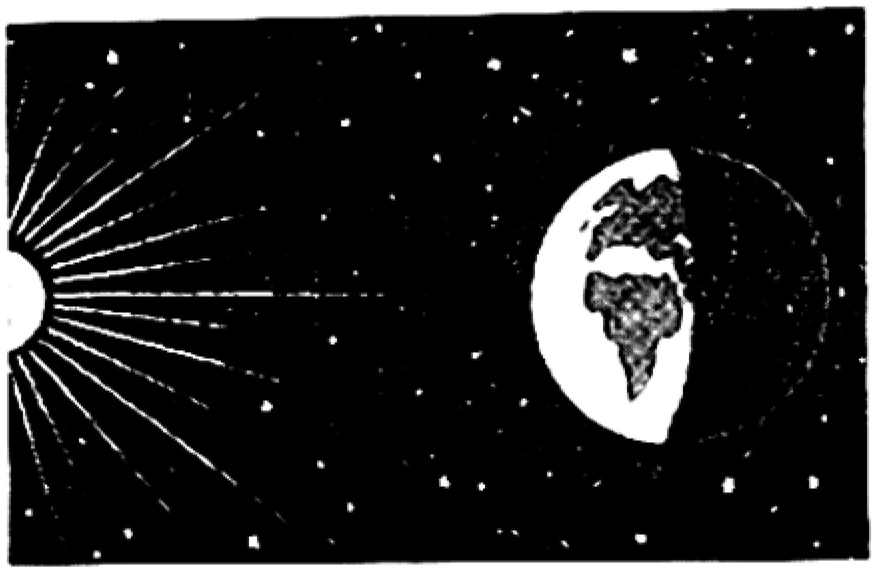
Your eyes are deceived in the same way when a ship leaves the quay. For a moment it seems that the quay is moving away from the ship.

Our Earth spins in space like a gigantic top.

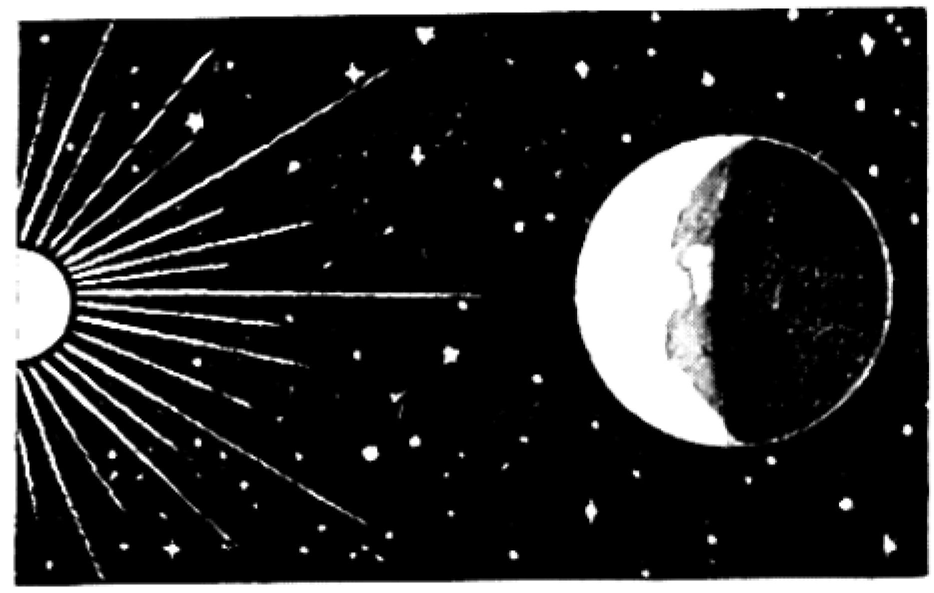
Set a top spinning and put a little piece of paper on it. It will be immediately thrown off the top. The force that throws the paper off is called centrifugal force or force that is pulling away from the centre, and it always appears when anything is spinning.

In amusement parks there are "joy wheels" that turn faster and faster and throw off people that are on them.

Why is it that the Earth, if it is spinning, does not throw off people and animals, rocks and sand and why does it not spill all the water out of the rivers and oceans?



When there is daylight in Europe and Africa it is night in America and Asia



Daylight in America and night-time in the Eastern Hemisphere

The answer is a simple one: the Earth is not spinning fast enough.

The "joy wheel" does not throw the people off as soon as it starts to move but only when it is moving fast enough.

The Earth turns from west to east and takes twenty-four hours to make one revolution. Man is so small in comparison with the Earth that he does not notice the motion, especially as the Earth turns very smoothly without any jerks or stops. And so we get the illusion that the Earth is standing still and the sky and all the bodies we see in it—the Sun, Moon, planets and stars—make one revolution round the Earth in twenty-four hours; the sky seems to move in the opposite direction from east to west.

You have your apple with the knitting-needle in it; the needle is the axis. The Earth's axis is not a steel needle but an imaginary line around which the Earth rotates; the length of the axis is more than twelve thousand kilometres. The length of the Earth's equator is about 40,000 kilometres.

What would the Earth be like if it were to revolve around the Sun with the same side always facing that luminary? What fierce burning heat there would be on that side of the Earth and what icy cold and darkness would be the lot of the other, unlit side! If this were the case life would be impossible on Earth. We have day and night, the Earth turns so that neither one side nor the other is either overheated or allowed to get too cold.

HOW DO PEOPLE KEEP COUNT OF TIME?

Can you imagine something quite improbable—a world without movement? How would time be measured in such a world?

In a strange, extraordinary land the sun stands still in the sky, not a breath of wind disturbs the leaves of the trees, the pale yellow flames of the fire lit by a hunter in the forest are motionless, the hunter himself sits by the fire without stirring, the hands of his watch do not move, a fox stands as though frozen stiff with one paw lifted to catch a mouse in the thicket and the mouse by its hole is just as still.... Is this a fairy tale? Yes, it is.

From time immemorial people have composed tales that include pictures of a sleeping kingdom. For three hundred years the king and queen of such a kingdom remained motionless with their counsellors and servants, with the sentries at the palace gates, the horses at the porch and smoke hanging fixed in the air.... And when the bold prince succeeds in removing the spell from the sleeping kingdom everybody goes about his business without realizing that they have all been asleep for three hundred years: where there is no movement there is no time!

Millions and thousands of millions of years before man appeared on the Earth and invented clocks, nature herself had produced the most accurate clock to indicate time. That clock is the Earth that rotates smoothly and regularly about its axis like a giant top and at the same time revolves round the Sun.

If it were possible to build a giant clock that worked by the motion of the Earth it would have two hands—the year hand and the day hand. The year hand would make one trip round the clock-face in a year and the day hand would show the time taken by the Earth to turn on its axis.

These are the two chief measures of time that have been given to us by nature. Everything else has been invented by man. It is in the power of man to make the week five or ten days long, he can divide the day into ten or forty hours and the hours would be shorter or longer than they are today. Human technology, however, is powerless to lengthen or shorten the day by so much as a second or make the Earth run faster round the Sun.

Why is the year divided into twelve months? The reason is the Moon. The word "month" comes from the same root as Moon and

that body travels round the Earth somewhat more than twelve times a year; this is why the year is divided into twelve months.

The months are divided into weeks of seven days. Here is an explanation of the English names of the days of the week.

The rest day is called Sunday, the day of the sun.

Monday is the day of the moon.

Tuesday is the day of Tiw, the god of war.

Wednesday is the day of Woden, the chief god.

Thursday is the day of Thor, the god of thunder.

Friday is the day of Frigg, the wife of Woden.

Saturday is the day of the planet Saturn.

As you see from this, traces of old religious beliefs, old customs and ceremonies are retained in the names of the days. This is the same in all languages.

The day is divided into twenty-four hours, the hour into sixty minutes and the minute into sixty seconds. Today most peoples are accustomed to counting in tens and hundreds so why not divide the day into two parts each of ten hours, and divide the hour into a hundred minutes and the minute into a hundred seconds? The hour would be slightly longer than at present and the minutes and seconds would be shorter but it would be more convenient if time were counted according to the metric system.


A sundial

This system has been proposed but it has never been put into effect, because to do so would mean throwing away hundreds of millions of clocks and watches all over the world and making new ones instead. Millions of books and textbooks would have to be rewritten and reprinted. And so this inconvenient method of counting time has remained just as it was handed down to us from ancient Balylon whose inhabitants counted in dozens and sixties.

From the days of antiquity to the present day people have used the most varied kinds of clocks to measure time. One type of clock used in olden days was the sundial; a vertical stake or marker was dug into the ground and its shadow moved round it with the Sun—long shadows in the morning and evening and shorter shadows at midday. By the position and length of the shadow people could tell the time. Minutes and seconds, of course, could not be even guessed at by this method and on cloudy, sunless days the clock did not work at all.

Sand and water clocks were also used. They told the time by the amount of sand or water that trickled from one vessel into another. Rich men had a special slave to watch the clocks; when the sand or water had all run out of the upper vessel into the lower he had to turn them round and whenever he did this he called out the time—"so many hours" from dawn—which made him a sort of "chiming clock."

Sand clocks are still used in hospitals and clinics to measure the time for various medical treatments and the familiar egg-timer is nothing but a little sand clock.

Much later clocks with weights and a pendulum appeared and last of all came the pocket watch worked by a spring.

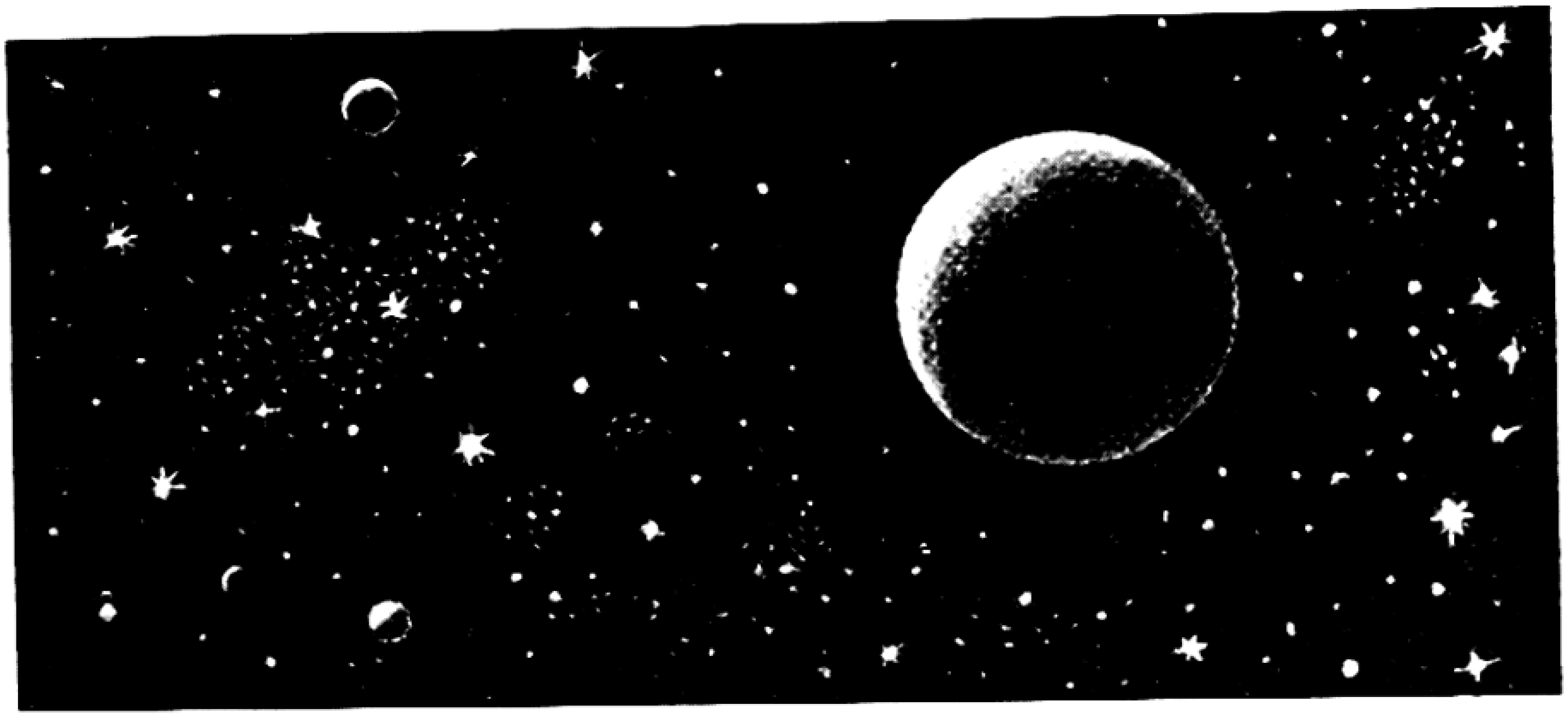
The greater the progress of science the more exact becomes our measurement of time. Exact time signals are broadcast by radio throughout the world.

Who needs such precise time? The captain of a ship needs it to find the position of his ship at sea; the aeroplane navigator needs it when his plane is flying by night or in foggy weather; the engineer and sportsman, the teacher and the pupil, all need to know the exact time.

But even what we call exact time is not exact enough for scientists; they have their own, higher class of accuracy since they have to count in thousandths and even millionths of a second.

The exact time for the whole Soviet Union is given by the Sternberg State Astronomical Institute in Moscow and Pulkovo Observatory in Leningrad.

Soviet engineers and astronomers have designed very precise instruments for determining the exact time by the position of the stars.



PART TWO

WHAT ARE THE STARS AND PLANETS?

The Sun is a huge fiery ball around which our Earth revolves. The Earth is about 150,000,000 kilometres distant from the Sun but even so it appears to us as a dazzlingly bright disc, and if we look at it for a minute or two it blinds us. It is safe to look at the Sun only early in the morning or late in the evening when it is low down over the horizon. At that time the rays pass through a thicker layer of air and lose some of their brilliance.

Suppose the Earth were to move farther away from the Sun—how would its appearance change? Obviously it would get smaller and smaller. And if we were to look at it from a distance of several thousands of millions of kilometres it would look like a tiny bright circle; it would not blind the observer no matter how long he looked at it.

If the observer were to move farther and farther away the Sun would seem like a star similar to many others to be seen in the sky on a cloudless night.

Our Sun is a star and it looks big to us because the Earth is quite near it. Every other star is a sun and is a tremendous distance away from us.

A star is a fiery heavenly luminary that has a temperature of many thousands of degrees. Every heated body gives off light—the

flame of a burning candle gives light, the white-hot wire in an electric bulb gives light and the lightning that darts through the clouds lights up the Earth. But the temperature of any star is much greater than that of a candle flame or of the filament of an electric light bulb. The distance from the Earth to some of the stars is much greater than the distance to the Sun—millions, even thousands of millions times greater—and yet we see them. This shows how brilliant these huge heavenly balls of fire are!

There are other bodies in the sky that do not give off light themselves but reflect the light of the big stars.

A mirror does not burn but if you point it at the sun it will reflect the bright rays of sunlight. The reflection is so bright that you cannot look at it. The reflection of the Sun's rays from a mirror can be seen over great distances and is made use of by soldiers to send signals.

It is not only a mirror that reflects the Sun's rays; they are reflected from your table and your books, from a carafe of water and from the pictures on the wall, from trees and mountains, from everything you see in your room and in the street.

Now try an easy experiment: close the shutters or pull down the blinds to your windows—instead of a bright sunlit room you find yourself in darkness.

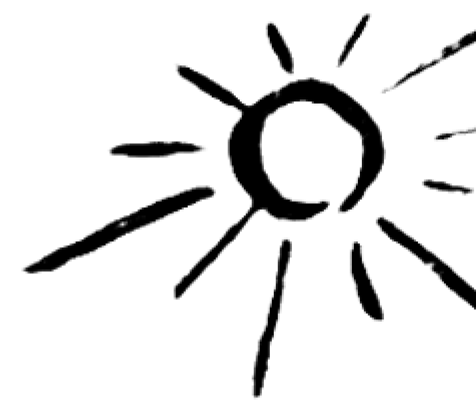
And what is darkness? We say it is dark when none of the Sun's rays, reflected from objects around us, reach our eyes. Now light a candle or switch on the electric light. Once more you can see everything although not as well as you could by sunlight.

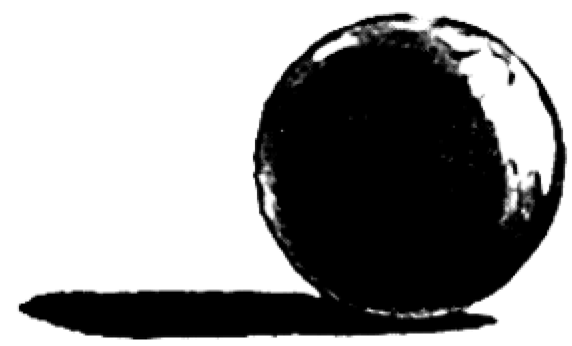
And so we see things that do not give off light only because they reflect the rays of some other bright object and transmit them to our eyes.

Why does the Sun's reflection from a looking glass blind us? And why can we look at other things lit up by the same rays such as your notebook on the table or the blanket on the bed and feel no discomfort?

Bright objects with a smooth polished surface reflect the Sun's rays all bunched together and it is this bunch of rays that blinds us. Objects that have a rough surface reflect the rays in different directions, they disperse them. The rays reach the eyes a few at a time and are not harmful.

In outer space there are bodies that are dark and cold. The nearest of these to us is the Moon. Then why can we see the Moon? Here, again, it is because we see the Sun's rays reflected from the surface of the Moon. The Moon has a rough surface, it absorbs many of the Sun's rays and disperses the others so that only a few of them reach our eyes.





Imagine the Moon with a surface like a looking glass. The Sun would then be reflected in it as an unbearably bright spot that you would not be able to look at. Actually the Moon is able to reflect very little light and its brilliance or luminosity is 437,000 times less than that of the Sun.

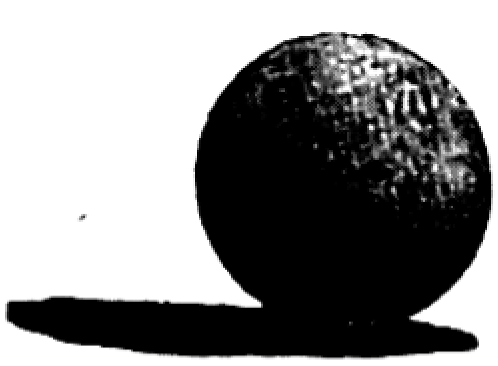
"But the Moon is quite bright," you will say, "we can see it as a bright circle or a crescent. The Moon lights up objects quite well and on a moonlit night you can see for quite a long way."

That is all true and can be explained this way.

The Moon is a big heavenly body. Its surface has an area of many million square kilometres and even if it reflects only a small part of the Sun's rays in the direction of the Earth, that small part contains quite a lot of rays and the disc of the Moon seems bright to us.

On a bright moonlit night the Sun's rays that reach your eyes have been reflected twice: firstly, they are reflected from the Moon and, secondly, from those objects on which the Moon's reflection falls, that is, the objects that you see.

Heavenly bodies that do not give off light but reflect the light of the Sun are called planets.



The Moon is a planet. But because it revolves round the Earth it is called the satellite or follower of the Earth.

Our Earth is also a planet and it reflects six times more light than the Moon. If you could look at the Earth from the Moon you would see it as a disc about fifteen times bigger than the Moon and about eighty times brighter.

But how have scientists been able to measure the brilliance of the light reflected by the Earth, that is, the Earth's luminosity?

At the time of the new Moon, when we see it as a tiny thin crescent in the sky, that part which is not lit up by the Sun has a scarcely noticeable silvery glow. This glow is to be explained by the fact that the Earth lights up the Moon and the latter reflects the rays that reach it from Earth. The silvery glow of the Moon is an example of doubly reflected rays—they are reflected from the surface of the Earth and then reflected a second time from the surface of the Moon.

As the crescent Moon increases in size its bright rays dim the gentle silvery light and we cannot see it any more.

By measuring the brightness of the silvery glow reflected from the Earth astronomers have been able to calculate the strength of the Earth's luminosity.

The Earth would be a very beautiful heavenly luminary for an observer who saw it from the Moon.

Here is a list of the planets that revolve about the Sun in the order of their arrangement in the solar system, i.e., their distance from the Sun: Mercury, Venus, Earth, Mars—these are called the inner planets; Jupiter, Saturn, Uranus, Neptune and Pluto are the outer planets. All except Mercury, Venus and Pluto possess satellites.

These are only the big planets. In addition to them there is a large number of small planets called asteroids, a belt of which divides the inner planets from the outer.

In January 1959 the number of small planets was increased by the artificial or man-made planet sent out from Earth by Soviet scientists.

FROM THE EARTH TO THE MOON

I expect you have often seen how a magnet and a piece of iron are attracted to one another. The power of attraction is called magnetic force or simply magnetism.

But not only magnets and iron, all other bodies in the Universe are attracted to each other. The power that does this is called the force of gravity. It is very difficult to notice this power of attrac-

tion in small objects: although they pull towards each other, the gravitation is very small.

The greater the mass of bodies the greater their pull or attraction for each other.

The heavenly bodies are of tremendous size and the strength with which they attract each other is very great even when they are far apart. The force of gravity is felt at any distance although it naturally grows less the greater the distance between the bodies.

The distance from the Earth to the Moon is 384,000 kilometres, but the force of gravity holds the Moon close to the Earth more surely than millions of steel cables would. This is why the Moon cannot fly off into space but must always revolve around the Earth.

The Moon is the Earth's satellite and we shall make it the first of the heavenly luminaries to examine.

The distance between the Earth and the Moon—384,000 kilometres—is not a very great one. There are airliners today that fly at 1,000 kilometres an hour and for them such a journey would be quite easy.

At a thousand kilometres an hour the journey would take 384 hours or 16 days and nights. All they would need would be food and water enough and, of course, plenty of fuel to get there and back.

And so we'll get on board a big airliner on which everything we need has already been loaded. What a great thing it is to be the first explorers of outer space!

The plane goes up and up. The needle on the altimeter (the instrument that shows height or altitude) points to 5, 10, 15 kilometres. Objects on the Earth get smaller and smaller; the rivers are tiny winding threads and the forests are dark patches.

But what is happening? Our plane does not go any higher. It remains at the same altitude although the engines are roaring away furiously.

"What's the matter?" we ask the captain.

"The air's too thin," he answers. "The plane cannot get enough lifting power."

"The farther we go the worse it will be," we tell him. "Soon there will be no air at all and only empty space in which the aeroplane cannot fly. Why didn't we think of it before? Let's go down, let's get down as quickly as we can and never tell anybody about this unsuccessful attempt!"

"Ha, ha," you will laugh, "what nonsense is our author writing! Are there people so silly that they think they can fly to the Moon on an airliner?"

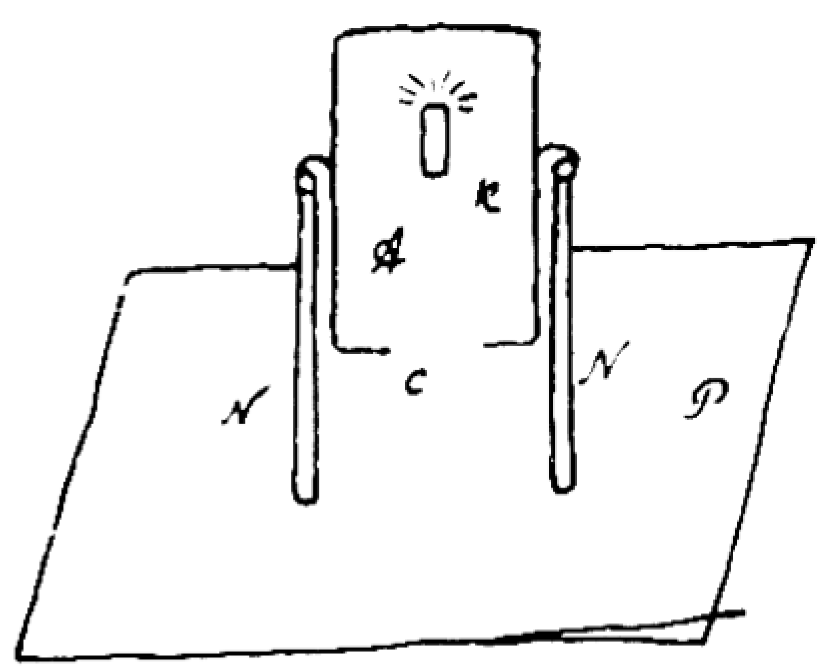
You are right, of course. And I suppose you know what sort of vehicle can fly to the Moon. The vehicle is called a rocket! And it is only on rockets that people will be able to travel in outer space because only a rocket can break down the force of gravity.

It is now time to explain what we mean by this force of gravity we have been talking about.

If you jump into the air in your room you will be back on the floor again in less than a second. An athlete throws a hammer, it describes an arc in the air and then falls back to the ground again a few dozen metres away. When a shell is fired from a gun it flies many kilometres through the air but always falls to the ground again. Everything in nature is pulled towards the Earth.

There was a time when people thought it would be impossible to break the chains of gravity. About eighty years ago a well-known French astronomer, Flammarion, wrote bitter words about Mars. "This is a New World," he said, "that no Columbus will ever reach."

But even as long ago as that the idea of a rocket vehicle that could carry a man had occurred to the Russian revolutionary Nikolai Kibalchich. In 1881 he was condemned to death by the tsarist government for participation in an attempt on the life of Tsar Alexander II. During his last days in prison before his execution Kibalchich thought over a number of scientific problems. It was then that he made a drawing of the rocket vehicle shown in our illustration and wrote a description of it. After the execution of Kibalchich tsarist officials kept the drawing in the state records and it was not seen again until after the Great October Revolution.



Sketch of a rocket vehicle made by Kibalchich while in prison awaiting execution

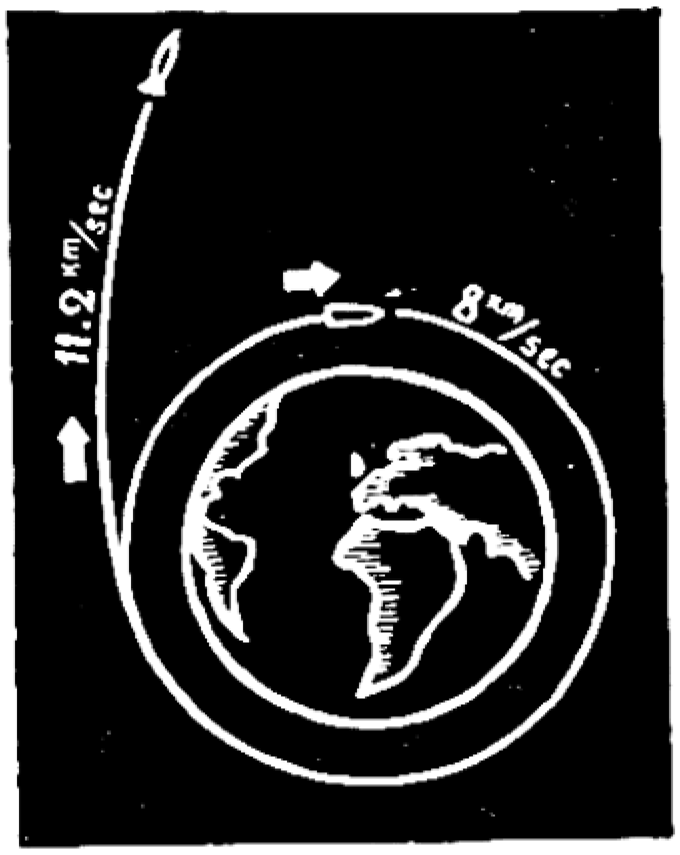
It is sometimes thought that a rocket moves by pushing itself forward against the air. But this is not true. An aeroplane in flight does rest on the air, but the air only hinders the flight of a recket by resisting it. Gunpowder or some other fuel burns in a rocket and produces gas, the gas flies out behind and pushes the rocket forward. This is the principle of jet propulsion and you, of course, know that there are plenty of aeroplanes today that are worked by jet engines and fly at great speeds at very high altitudes.

There was a distinguished Russian scientist, Konstantin Tsiolkovsky, who devoted all his long life to the study of the possibility of travel between the planets. As long ago as 1903 he published the first drawings and calculations for a rocket-ship that would travel from planet to planet. Later he designed a multi-stage rocket that would overcome the gravitation of the Earth. This was a rocket built of several parts or stages. First the fuel in the last stage would burn out and send the rocket up into the air at a speed that was not too great. When the fuel in this stage had all burnt out the whole stage would drop off and fall back to Earth. Then the second stage would begin to work and would increase the speed of the rocket which was now much lighter. After this stage broke away and fell to Earth the third would begin and the rocket would gain a very high speed. The last stage would gain such a high velocity that it would not fall back to Earth. It had been proved that the Earth's gravitation could be overcome only by a very high velocity.

The jumper lands back on the floor, the hammer falls to the ground and the splinters of a shell are scattered over the Earth. Why does this happen? It is only because they do not move at a high enough velocity to fly into outer space.

But remember: the jumper rose one or two metres from the floor, the hammer flew up between ten and twenty metres and the shell reached a height of several kilometres. That was because the speed of the hammer was much greater than that of the jumper and the speed of the shell was many times greater than that of the hammer.

The shells of the biggest long-range guns leave the muzzles at a velocity of about two kilometres a second. This is a very high speed. At such a speed it would be possible to fly from Leningrad to Moscow in about five minutes. Still, this speed is not great enough for the shell to get out of the Earth's gravitational field. It



will describe a tremendous arc in the air and then fall back to Earth again.

Tsiolkovsky calculated that if a rocket be given a speed of eight kilometres a second it would not fall back to the ground but would revolve around the Earth and become an artificial satellite or man-made moon. This was the speed at which the first Soviet sputniks were sent up. It is called Circular Velocity because the satellite circles round the Earth and does not leave it.

If a rocket attains a velocity of 11.2 kilometres a second it will break away from the Earth and can be sent towards the Moon, Mars or any other planet. This speed is called Escape Velocity.

The first pathfinder seeking the way to the Moon was the space-rocket launched in the Soviet Union on January 2, 1959. It flew past the Moon and became a satellite of the Sun, that is, the first man-made planet of the solar system. This was an event of such great importance that we shall have more to say about it later on.

Now imagine that the day has come when the first people are setting out on a journey to the Moon and that we are passengers on the first interplanetary rocket liner.

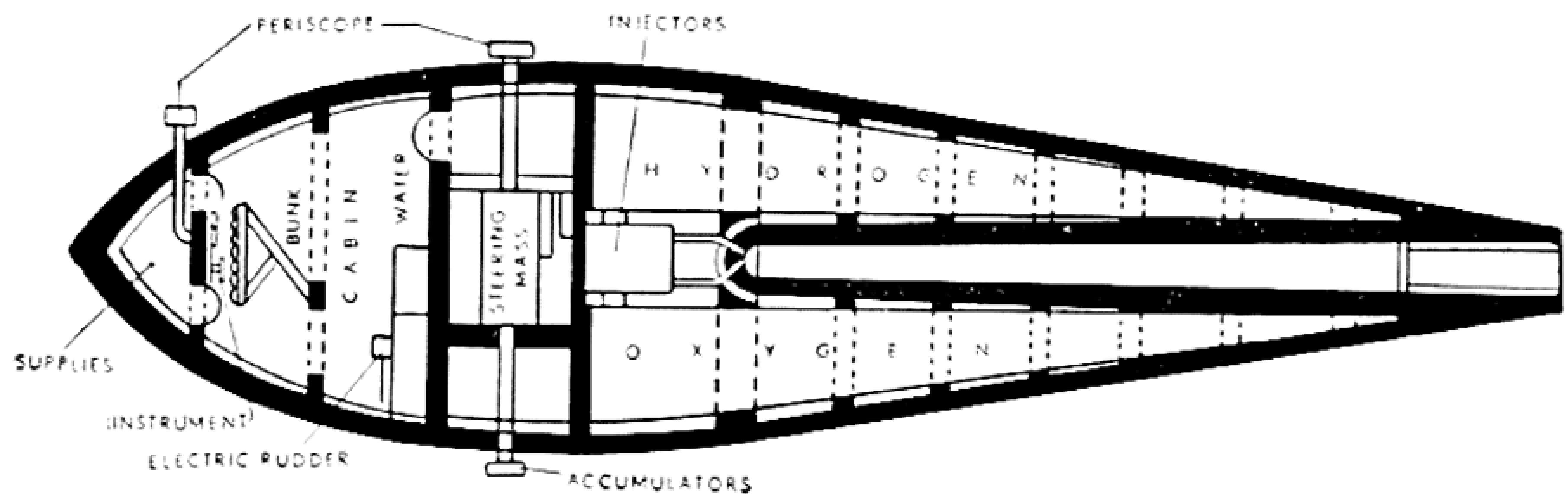
The rocket-ship, unlike an aeroplane, will not stop after passing the outer limit of the Earth's atmosphere. On the contrary, it will begin to move faster because there is no air to resist its motion. The speed of the rocket-ship must be increased gradually so that there will be no jerks. You remember what happens in a tram-car when it moves suddenly forward—all the passengers are thrown backward.

Our rocket will be controlled from the Earth by means of radio signals. The instruments on board the rocket will obey those signals and the speed will be gradually and smoothly increased and the rocket will follow the path given it.

Faster and faster our rocket-ship flies through space. The Earth is far behind us and the rocket is moving at a speed of about 25,000 kilometres an hour. This is a tremendous speed, might it not do harm to the passengers? Not the slightest. Man does not feel

speed, no matter how great it is, as long as it remains the same all the time. Only sudden jerks forward or sudden stops are harmful to him.

At last the rocket attains the velocity needed and the motors stop working for fuel must be economized. Now it will move at an almost even speed like a skater flying over the mirror-like surface of the ice.



One of the designs for an interplanetary rocket

The skater's speed will be reduced by the resistance of the air and by the friction of his skates on the ice no matter how smooth it may be.

But what is there to slow down a rocket in empty outer space? The Earth's gravitation. Although the rocket has flown far away from the Earth it still feels the pull of the Earth and this force of gravity will continue to make itself felt, although it will get less and less as the two bodies, the Earth and the rocket, draw away from each other. The force of attraction acting on our rocket-ship is now much smaller than when it first left the Earth but it is still enough to reduce the rocket's velocity.

If the rocket were to fly so far away from the Earth and the Sun that their gravitation no longer acted upon it, the vehicle would continue hurtling through space for centuries and millennia, as long as it did not approach another body that would attract it towards itself.

Our journey, however, will not be a long one. It will take about 36 hours, including the time taken when the rocket was gradually increasing its speed in leaving the Earth and the time taken to approach the Moon, when it gradually loses speed.

The passengers can look through small round windows in the bows of the space-rocket as they would through the portholes of a ship. These portholes are made of a special kind of glass and are very thick and much stronger than steel. Everybody is anxious to get a good view as the vehicle approaches the Moon.

You and I will sit at a vacant porthole, the one next to the map of the Moon's surface will do splendidly. From here we can watch the Moon and find places on it that are marked on the map.

As we look at the Moon it seems much bigger to us than it did when we were on Earth. By this we realize that we have already covered half the distance to our destination. The Moon still appears to be a flat disc, like a huge silver coin with a lot of dark patches on it. But as we draw nearer to the Moon it grows more and more convex: the centre seems to bulge out while the edge of the disc begins to drop back. And soon we see quite clearly that the Moon is a huge ball or sphere that is hanging freely in empty black space and behind it, immeasurably distant from us, thousands of stars are shining.

We are able to make another interesting discovery: the stars are not twinkling in the sky, they are tiny spots of bright light. The spots are so small that we cannot measure their diameter. Stars only twinkle when you look at them from the Earth.

You have probably noticed how the air trembles and shimmers on a hot summer's day and objects in the shimmering air also seem to quiver and their outlines are slightly distorted.

The same thing happens when we look at the stars, because the air above the Earth is very seldom calm. This changes the apparent shape of the stars and they seem to spread and look much bigger than they should but not so bright.

The view of the starry sky as seen from the space-rocket is marvellous. There is nothing that can be compared with it for sheer beauty. But we fix all our attention on the Moon, that huge ball that gradually grows bigger and bigger.

And we certainly made no mistake in setting out on this wonderful journey for we are learning something new all the time.

When you look at the Moon from the Earth with the naked eye you see some dark patches on it. Before the telescope was invented people could not make out what these patches really were. All sorts of fanciful explanations were given, the most popular being

that the Moon is a human face. On very old maps the Moon is drawn with a nose, eyes and mouth.

Through our porthole we see the surface of the Moon with chains of mountains whose summits are lit up by the Sun. We see strange mountains that astonish us earthlings—these are the craters and cirques or circuses. It is true that the lunar craters are shaped like those of the volcanoes on Earth, but they are dozens of times bigger. They look like mountains whose tops have been cut off and in place of the summits there are huge round hollows in the middle of which there is sometimes a tall pointed hill.

The cirques are even bigger than the craters; they look like round plains with a high ring-shaped wall or rampart round them. Some of these cirques are very big and could contain a small country, Switzerland, for example.

Let us try and count the craters and cirques that we can see on the Moon. One, two, three ... ten ... twenty ... fifty....

We very soon have to give it up for there are thousands of them! But all these craters and cirques are marked on our map of the Moon and every one has a name. We read on the map: Crater of Copernicus, Crater of Galileo, Ptolemy's Cirque.... The majority of them have been named in honour of astronomers and other scientists.

But what's that? There is no longer dead silence in our rocketship: the hull of the vehicle begins to tremble from dull explosions—now we can hear them directly under our feet. Guess what is happening. The rocket motors in the nose have begun working to put the brakes on the rocket and slow it down. The rocket would be shattered to the finest dust if it were to crash on to the Moon at the speed of 2.4 kilometres a second, the velocity at which the rocket approaches that body.

The deceleration or slowing down of the rocket increases and we are all pulled forward irresistibly. We grab hold of the stout straps fixed to the walls so as not to fall.

The Moon no longer shines, it seems to be moving towards us like a huge black cloud that covers most of the sky.

We are just a little bit scared—how will the landing of the first passenger rocket to the Moon go off?

The Moon draws closer to us but more and more slowly. Now it is right under our feet and in order to look at it we must go to

Lunar craters

the central part of the rocket vehicle where there are portholes in the cabin floor.

We feel that the rocket is falling on to the Moon's surface.

Now we are at a height of only a few kilometres above the Moon. Below us there is a dark plain of tremendous size that is broken here and there by huge crevasses and is dotted with hills quite a distance apart.

Suddenly we hear the captain's voice in the loudspeakers:

"We are now over the Ocean of Storms. We are going to land on it. Everybody prepare to land. Take a strong hold of the straps!"

The Ocean of Storms! Does that mean we are going to come down on water? It does not look like it: not a lake nor even a small river is to be seen anywhere.

One of the passengers, a grey-headed professor of astronomy, explains the name to us.

"When astronomers first turned their telescopes towards the Moon they saw that it was a whole world with chains of mountains, craters and huge dark patches. These dark patches are the plains of the Moon but astronomers used to think they were seas and oceans. And so we get on our map of the Moon such names as the Ocean of Storms, the Sea of Rains, the Sea of Clarity, Decayed Marsh...."

(On English lunar maps the names are usually given in Latin,

Mount Picot on the Moon

such as Oceanus Procellarum, Mare Imbrium, etc.) "Actually there is no water at all on the Moon as we shall soon see for ourselves."

Our rocket-ship is already quite close to the Moon. Huge things like legs move out of the body of the rocket; these are the landing struts on which the ship will land and they are fitted with powerful spring shock absorbers to lessen the impact. A sudden bump, and we all lose hold of the straps and tumble over each other on the floor.... The rocket-ship is standing still!

Again we hear the jubilant voice of the captain in the loudspeakers:

"Allow me to congratulate the first Lunar Expedition on a safe landing! Get ready to leave the ship!"

What are we going to see in this strange, alien world?

ON THE MOON

The captain told us to get ready to leave the ship but what sort of preparations must we make?

We have been warned that there is no air on the Moon. If any of the interplanetary travellers were to go out of the ship for a short walk on the Moon he would die immediately. The air that is

inside him would try to expand and fly out into the empty space around him, it would burst his lungs and other internal organs.

But nobody even dreams of such a reckless action. A special space-suit has been made for every member of the expedition to his exact size; it looks something like a diving-suit. These costumes with glass-fronted helmets are really much better than diving-suits. When a diver goes down into the water a rope or cable is fixed to his helmet and he is always "tethered."

Our space-suits are wonderful things that we can go anywhere in because they contain chemicals that give us oxygen to breathe and other chemicals to absorb the carbonic acid gas we breathe out. The air inside the helmet is always fresh and easy to breathe.

The front of the helmet, its face, is made of thin but very strong unbreakable glass. A tiny radio receiver and transmitter built inside enable us to talk with our companions; all the radio sets are tuned to the same wavelength. Wires from tiny but powerful batteries run through the air- and water-proof textiles of which the suit is made and keep it warm so that we need not be afraid of the most severe frosts. The heat can be switched on and off as we require.

A wonderful costume! But, still, we look at it in alarm—it is such a clumsy-looking thing. We'll have to crawl about in our suits like tortoises in their shells.

The professor of astronomy laughs at our doubts.

"Don't be afraid, get into them. You'll not only walk, you'll jump about like grasshoppers in those suits!"

Now everything is ready and we make for the exit. Sure enough, it is not at all difficult to walk. We feel a sort of freshness throughout the whole body and our muscles seem to have become stronger.

Here we are at the door. It is not a simple door, like that of a tramcar or even an airliner; this door is a whole room. We enter it from the cabin and the captain closes the door carefully behind him.

Ha, we guess, he's doing that so that the air won't fly out of the rocket. Then the pumps begin to work, pumping the valuable air out of our doorway which is called an airlock. Now we open the outer door, go down a ladder and step on lunar soil.

Incidentally, what are we to call it? On our native planet we walk on the earth, we can stoop down and pick up handfuls of earth, but here?. . . It seems silly to say: "I've got a handful of moon or I threw some moon at my friend!" And so we have to use our old words: I walk on the earth, I fall to the ground. But we have to remember that here the ground is lunar ground.

But what's that over there? Somebody has got here before us—we are not the first people on the Moon! In the distance we can see another rocket exactly like ours with its polished walls gleaming in the sunlight.

"Captain!" we all shout at once, "you told us. . . ."

The captain raises his hand, asking for silence. It will be interesting to hear how the captain will explain the presence of another rocket on the Moon in the very place that we chose to land.

"Don't get excited," says the captain. His voice comes to us clearly in our helmets. "Everything is all right. That is a Soviet rocket and it's been here for six months."

"As long as that? And where are the people?"

The captain laughs.

"There aren't any people. This is an automatic rocket that flew through space from the Earth to the Moon in obedience to radio signals, the same as ours did. It was launched automatically and on its way increased and decreased its speed automatically on the orders of a captain on Earth where there was a special pilot's cabin exactly the same as that on our rocket."

"And who was that captain?"

"I was the captain. I must admit, my friends, that I was very anxious about the landing of the automatic rocket. It was a very stiff examination: if the rocket had been smashed in landing, our expedition would have been put off for many years. There would have been more calculations, experiments and test flights. Our Government would not have sent people to the Moon if there had been the slightest danger that they would be lost! But everything went well, the rocket landed—I can't say "mooned," or perhaps I can, what do you think?—safely and just over a second later we got a signal from the self-recording mechanism on the rocket."

"How interesting! But go on, captain, excuse us for interrupting you."

"The director of the Interplanetary Travel Research Institute congratulated me and handed me my diploma, the certificate of a spaceship pilot. That is why we are all here. But let me continue. The automatic rocket, autorocket for short, sent out a baby tank in obedience to my radio orders; the tank was supplied with fuel for several hundred hours journey. I directed it by radio and it travelled all round this part of the Moon and its television transmitter sent us an exact picture of the Ocean of Storms which proved a very convenient landing ground. I deliberately landed near the autorocket because it has on board a big supply of fuel, food and water; our passenger ship could not take on board such a big load. The most important thing of all—the tank is still in good working order and will serve us to explore the surface of the Moon."

"Hurrah!" we all shout in chorus. "Come on to our lunar neighbour that has already served us many good turns."

"And will do for us a lot more in the future," added the captain.

We set out on our way but suddenly come to a halt. How unfortunate! A big crevasse or crack in the ground bars our way. It is about thirty metres deep and a good seven metres wide and stretches to the right and left as far as we can see. It is something we cannot cross and cannot get round, so what shall we do? Shall we have to build a bridge? What from?

But look! The old astronomer is running boldly towards the deep crevasse as though he intends to jump across it.

"You'll kill yourself, professor!" we shout and wave our arms to him.

But the professor leaps, flies lightly across the crevasse and lands gently about five metres beyond its steep side.

The astronomer turns to us and shouts merrily:

"Follow my example and jump!"

We are a bit scared but we all jump and fly across the crevasse like birds. One young sportsman jumped so far that he fell in another crevasse about eight metres from the first. Luckily it was not very deep and he did not hurt himself; he soon came crawling out, laughing at his adventure.

We all turn to the professor.

"Tell us what it's all about, please. How can we jump so far?"

"The Moon is much smaller than the Earth and its gravitation is much less," answers the professor. "The force of gravity here is six times less than on Earth and that means that everything on the Moon weighs only one-sixth of what it does on Earth. On the Earth I weighed sixty kilograms and here I weigh only ten. But my muscles are still the same as they were before. That's why I can jump six times farther than on Earth. Then, again, there is no air here to resist the movement of objects."

Everybody is very pleased with this state of affairs. It seems that without the slightest trouble we have all become six times stronger.

The weight of a man on the Moon (on a spring balance)

We step out boldly and happily on lunar soil and look around us with curious eyes. All round us there is a dreary, dusty plain. The dust that we kick up with our feet flies up and settles again slowly: there is no wind here that could raise clouds of it. The dark brown soil gleams so brightly in the Sun's rays that it hurts our eyes to look at it.

We raise our eyes to the sky and there we see our own familiar Sun. It looks just the same on the Moon as it did on Earth. This is easy to understand for the distance from the Earth to the Moon is very small compared with the distance to the Sun. A telegraph pole will seem the same size to two people who look at it from distances of 1,000 and 998 metres.

The view of the sky is very different. We knew before we came that the Moon's sky is black but here we see a lot of stars and the Sun does not make them dimmer with its bright light. The tiniest stars are visible, even those that are close to the Sun's disc. On Earth, the particles that make up the air are illuminated by the light of the Sun but they dim the rays coming from the stars so that we cannot see them in daytime. There is nothing to hinder them on the Moon and light rays from the dullest star reach our eyes.

But what is that big bright crescent hanging low over the horizon? It looks like the crescent Moon seen from the Earth, only it is several times larger.

Is that some planet?

Of course it is, it is our own Earth that we have left, luckily, only for a short time. As we look at it from the Moon it is sending us the Sun's rays reflected from its surface. And so we can see with our own eyes that our Earth is a heavenly luminary like any of the others, like the Moon, Mars, Jupiter and other planets.

Now that we have sufficiently admired the bright crescent of the Earth we must go to take a look at the autorocket.

It is standing firmly on its supporting struts. The captain presses a button on one of these legs, a light ladder of aluminium alloy slides down and he mounts it and opens the door with a key he has brought with him. As he enters the rocket we follow him, filled with curiosity.

We do not find anything new inside the rocket except that the usual accommodation for passengers is filled with fuel, food and water. The pilot's cabin is the same as that on our rocket and all the instruments have special relays that receive radio signals sent from Earth, amplify them and transmit them to the rocket's mechanism.

"It's time to go home!" says the captain. "We can have supper and go to bed!"

"To bed? Why, the Sun is still high up in the sky!"

The professor laughs at this.

"You'll have to wait a long time for your sleep if you wait for sunset! The lunar day lasts about three hundred and fifty Earth hours. Although the Sun has begun its motion towards the horizon it won't set for several earthly days yet."

We ask the astronomer to tell us why the Moon's day is so long. But he tells us we'll have to wait until we get back to our rocket.

We approach the huge rocket-ship, the captain opens the outside door and counts us as we go in to make sure that everybody has returned. Then he closes the outside door, starts the pumps going to fill the lock with air and only then opens the inside door to the ship. We take off our space-suits and find that a good stretch is a pleasant thing after spending several hours in a costume that restricts movements.

After we have finished supper and are lying on our comfortable collapsible bunks the professor tells us about the Moon.

"The Moon always has the same side turned to the Earth and that side we'll call its face. You all know the map of the Moon but that map only shows one half of it. The other side of the Moon, its back, if you like, has never been seen by anybody although it has been photographed by a Soviet Automatic Interplanetary Station (see pp. 99-104). Since our captain intends to go there we shall be its first explorers. But why is it that the Moon always shows only its face to the Earth? It is because the Moon in the course of its long

orbit round the Earth turns only once on its axis! If that is not quite clear to you try a simple experiment. Take a ball that is painted in two colours, say, one half red and the other blue. Let the inkpot on the table represent the Earth. Now turn the ball round the inkpot so that the red hemisphere faces it all the way round. You will see that as you passed the ball round the inkpot it turned in your hands on its own axis one whole revolution. You can try the same experiment with other objects. You can, for example, pass a watch round the inkpot so that the figure six on its face is always turned to the inkpot. That length of time which we earthlings call a lunar month would be called a lunar day by the moonfolk, if there were any. The length of the lunar day and night is twenty-nine and a half of our Earth days and they are equally divided between light and darkness, day and night."

"And so the night here is also three hundred and fifty-four hours?"

"Quite right, as we shall soon see."

A sum in simple arithmetic soon tells us that there are only about thirteen lunar days in a whole Earth year. If there were people on the Moon they would see only thirteen sunrises and sunsets in the course of a year.

We do not sleep for a long time as we ponder over all the new things we have seen today.

EXPLORING THE MOON

The captain fixed a strict time-table for all the members of the expedition: sixteen hours waking time and eight hours sleep.

The exploration of the Moon began. Geologists searched for minerals, the astronomer studied the stars and the Earth and the captain with one of the crew made some difficult descents into deep crevasses and craters.

In 1948 the Soviet astronomer Y. Lipsky discovered that the Moon has an atmosphere: he estimated that it is about two thousand times rarer than the Earth's atmosphere. It is possible to find even such greatly dispersed gases by using very sensitive instruments.

But where are these lunar gases to be found? If we take a glass of water and let a few drops of mercury fall into it they will immediately sink to the bottom because mercury is heavier than water. The gases should also sink to the lowest part of the Moon, that

is, the bottoms of the craters and crevasses. And our captain discovered that there really were gases in the deep cracks.

We reported this in one of the telegrams we sent back to Earth every day.

The lunar day was coming to an end. The Sun was sinking towards the horizon. Its rays slanted down to the Moon and no longer heated its surface as they had done earlier. It began to grow dark in the valleys and crevasses but the mountain peaks were still lit up by the Sun.

The crescent Earth that hung in the sky was growing in size and shining more brightly.

The little baby tank in which we travelled over a large area of the Moon was hermetically sealed and we were able to take off our space-suits inside it.

The Moon is a dismal lifeless world. Its extremely rarefied atmosphere does not transmit sounds, everything is silent and dead. If it had not been for the radio we should not have been able to talk with each other during our excursions. But even the radio functioned only as far as we could see because there is no ionosphere about the Moon like that of the Earth's atmosphere that reflects radio waves and sends them back to be received anywhere in the world.

Above the Moon you will not see clouds tinted all colours from rosy pink to deep, dark red at sunrise and sunset. As there is no water there is no green grass and no trees. Owing to the absence of an atmosphere only two colours predominate on the Moon—black and glaring white. Everything gleams brightly in the Sun and the shadows are deep black.

And the heat on the sunlit side of the Moon! The hull of our rocket vehicle did not conduct heat so that the temperature in the cabin was normal, but when we went out everybody had to take a huge umbrella with him to protect him from the merciless, burning rays of the Sun. You would not be able to go far with such an umbrella on Earth for the first gust of wind would tear it out of your hands. On the Moon, however, there is practically no resistance in the extremely rarefied atmosphere and the umbrella did not hinder us when walking or jumping. The lunar soil was heated to a temperature of $+100^\circ$ C. in the daytime and we had to wear shoes with soles that did not conduct heat. Only if you take all these precautions can you go walking about the Moon in daytime.

And so the Sun slowly, very, very slowly, sank towards the horizon. This sunset lasted several hours. Darkness engulfed the plain but the tops of the distant mountains remained brightly lit up for a long time; they were brighter than the brightest stars. At last they, too, went out. The temperature dropped until it was —150° C. Our rocket was heated by powerful electric stoves and whenever we went outside we immediately switched on the heaters in our space-suits for it would not have taken us long to freeze to death in such a temperature.

With every passing hour the crescent Earth grew larger and larger until at last it was a complete circle. The time of "full Earth" had come. The "full Earth" shone with a brilliance eighty times greater than that of the full Moon. So brilliant was it that we were able to make many long earthlit trips across the Moon as we did not fear the frost.

If there had been people on the invisible side of the Moon they would have had something to regret: never seeing that magnificent spectacle of the "full Earth" shining with its soft bluish light against the background of a black sky over which countless stars were scattered.

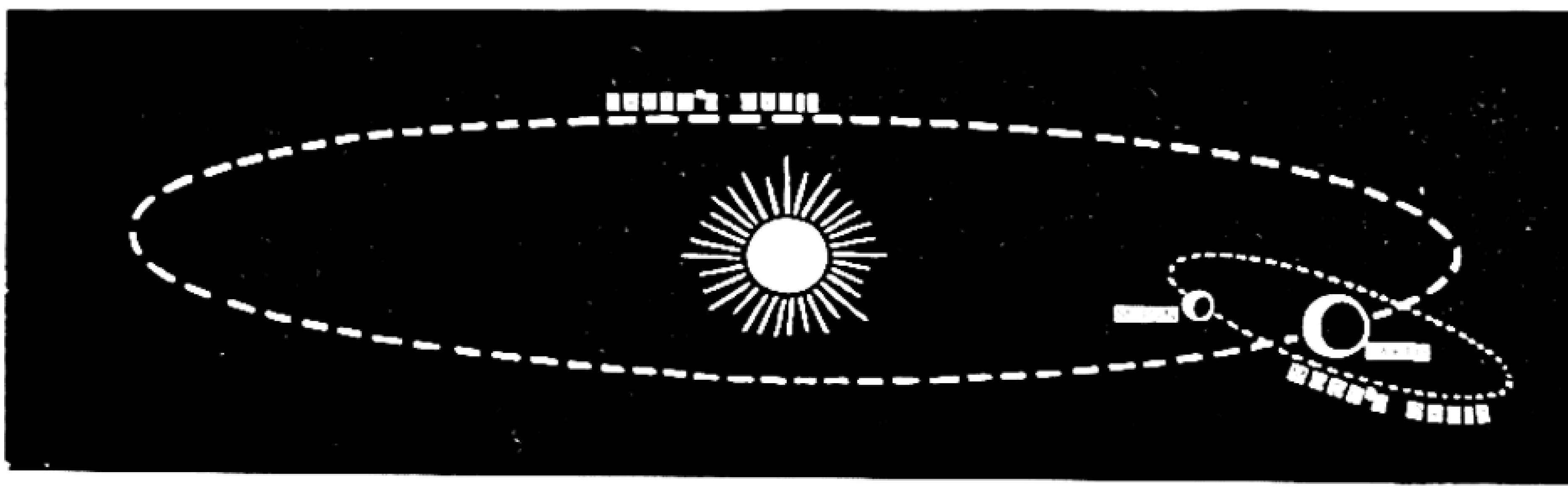
In illustrations to science-fiction stories that depict the Earth as it is supposed to be seen from outer space it is usually shown with the continents and oceans in the same way as they are drawn on a globe.

But we saw for ourselves that these pictures are incorrect; when you look at the Earth from outer space it looks like a bright, bluish disc and neither continents nor oceans are visible on it.

The astronomer told us that this was due to the Earth's atmosphere which is very dense and very thick and has clouds and a tremendous number of dust particles in it. All this forms a barrier to the Sun's rays as they are reflected from the Earth's surface and prevents the observer in outer space from distinguishing continents and oceans.

As we studied the Earth in the Moon's sky we could easily understand what causes the changes in the appearance of the Moon, the so-called lunar phases. When the face of the Moon that is turned to the Earth is not lit up by the Sun it is called the new Moon; we do not see the Moon at this time because it does not send reflected sunrays to us. Then the Moon is gradually lit up by the Sun from one edge and we see its thin crescent in the sky. The crescent

grows as the Moon turns its face to meet the Sun's rays. When one half of that part of the Moon that we can see is lit up by the Sun we say that the Moon is in the first quarter. At last the whole of the Moon's face is lit up by the Sun and we have a full Moon. After this the Moon's face gradually turns away from the Sun, again we see only a half of it, the last quarter. At last the Moon disappears altogether; this is when the Sun is shining on the hemisphere that we do not see and for people on Earth it is the time of the new Moon again. A whole lunar month has passed and everything is repeated during the next month.



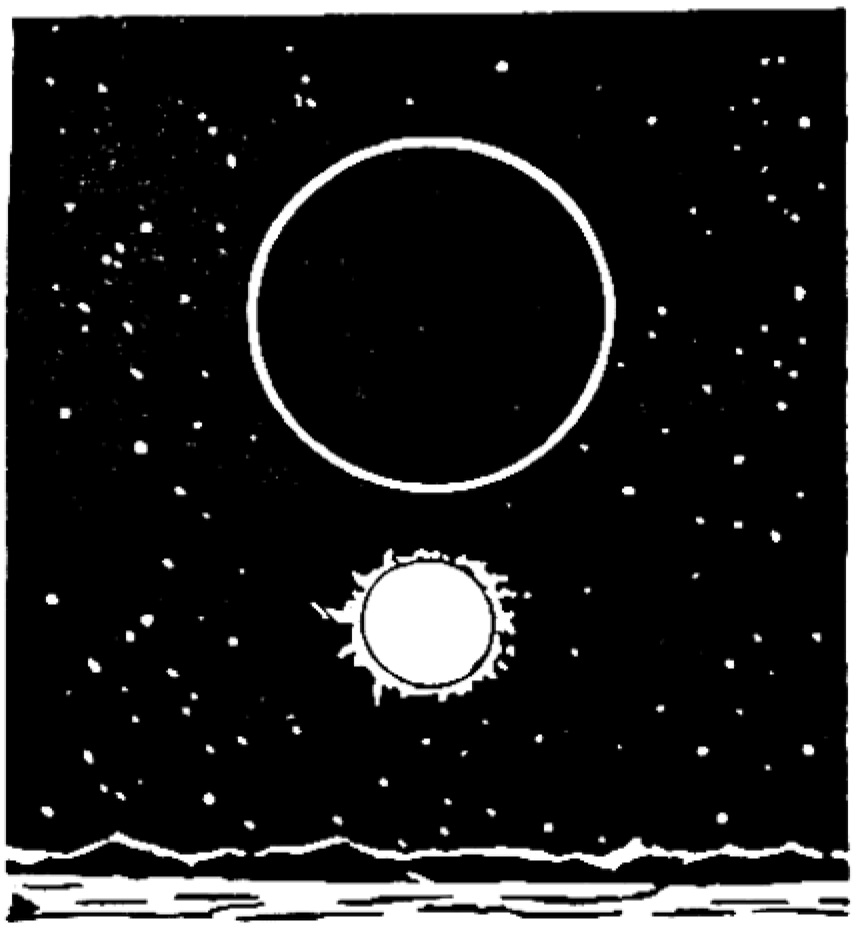
The Earth, accompanied by the Moon, revolves round the Sun

The phases of the Earth as seen from the Moon are the opposite of the lunar phases. When there is a full Moon on Earth there is a "new Earth" on the Moon and when the Earth has a new Moon the Moon has a "full Earth."

When half the lunar night had passed our space vehicle and its crew began to make preparations for the return journey to Earth. The supplies of fuel were brought to our rocket and things that we did not need for the return journey were packed away in the autorocket.

It was much easier for the rocket to take off from the Moon than it had been from Earth. The weight of our rocket was only one-sixth of its earthly weight and it was necessary only to reach a speed of 2.4 kilometres a second to get away from the Moon and fly off into outer space.

A long-range gun whose shell has a muzzle velocity of two kilometres a second would be quite useless on the Moon. The shell would not fall back on the Moon but would become a Moon satel-



The new Earth as seen from the Moon

lite and revolve round and round it like a tiny planet.

The moment for the take-off came. Everybody took his place in the main cabin while the captain sent a radio telegram to Earth.

The rocket's hull trembled with the force of the explosions and in a few moments the dark plain of the Moon was far away behind us.

Good-bye, Moon! We're coming back to you, we'll wander over your dusty plains again and we'll climb your mountains and go down into your deepest crevasses.

But in the meantime—homeward bound! Hour by hour the Earth grows bigger and bigger but at the same time it becomes paler.

At last came the moment when the huge mass of the Earth filled the whole sky. The rocket's motion had long since been checked but the speed was still far too great. We could not have landed on the Earth at such a high speed. On Earth, however, we had a splendid brake such as we had not had on the Moon—the dense atmosphere.

The interplanetary rocket vehicle entered the upper layers of the atmosphere. It went down at a slant, losing altitude very slowly for the resistance of the atmosphere acted as a strong brake. The lower we flew the denser became the atmosphere and the speed of the rocket was greatly reduced. When it had begun to fly at the normal speed of an aeroplane our captain directed his course towards Kuibyshev Sea and brought the ship down right in the middle where it rocked on the waves like the float of a giant fishing line.

The wonderful journey to the Moon was over. And how splendid it would be if we could make such a journey in reality and not just imagine it!

We can be sure that before much more time has passed such journeys will become quite usual. Scientists are trying to shorten that time by hard work and by research in outer space.

In 1955 the Astronomical Council of the U.S.S.R. Academy of Sciences set up a Standing Commission on Interplanetary Travel. The Commission includes the leading Soviet scientists working in the fields of physics, mechanics, astronomy and mathematics.

The Commission has undertaken as its first task the establishment of a space laboratory. The idea of such a laboratory occurred to Konstantin Tsiolkovsky many years ago.

The space laboratory will be a new Earth satellite, its second, that will revolve around the Earth outside its atmosphere at a distance of about 40,000 kilometres. This station outside the Earth's atmosphere, or extra-terrestrial station, as scientists call it, will be surrounded on all sides by empty space and scientists will live on board it to make observations that cannot be made from the Earth. The Moon and other planets will be studied far better than they are at present.

The extra-terrestrial station will become an interplanetary platform from which rockets proceeding to the Moon, Venus and Mars will be launched at a much lower velocity than is necessary on Earth.

The building of an extra-terrestrial station is a matter for the near future. The artificial Earth satellites now in use are the forerunners of such a laboratory.

SOVIET PENNANTS ON THE MOON

Until quite recently, even scientists working in the sphere of interplanetary travel believed that journeys to the Moon, such as the imaginary journey we have just described, were a matter for the distant future. Science and engineering, however, have developed so rapidly in recent years that it is now possible to forecast the first manned flight to the Moon at a much nearer date.

On September 12, 1959, a space vehicle was launched from the territory of the Soviet Union in the direction of the Moon; it reached the Moon on September 14 at 00 hours 02 minutes 24 seconds Moscow time. For the first time in history a flight from one heavenly body to another had been made in reality and not in the fantasies of Jules Verne and H. G. Wells.

This new Soviet achievement made a tremendous impression on scientists all over the world. Professor Lovell, Director of Britain's radio-telescope observatory at Jodrell Bank, said that the rocket

flight to the Moon was "a brilliant demonstration of the advanced stage of Soviet science and technology.... To guide an object like this over a distance of a quarter of million miles is a feat at which the mind boggles."

The French professor Ananoff, a member of the International Astronomical Union, who specializes in the study of the Moon, said that from what was known of Russian possibilities they could probably do even more and if they wanted to make a rocket still more astounding they could put a man on board.

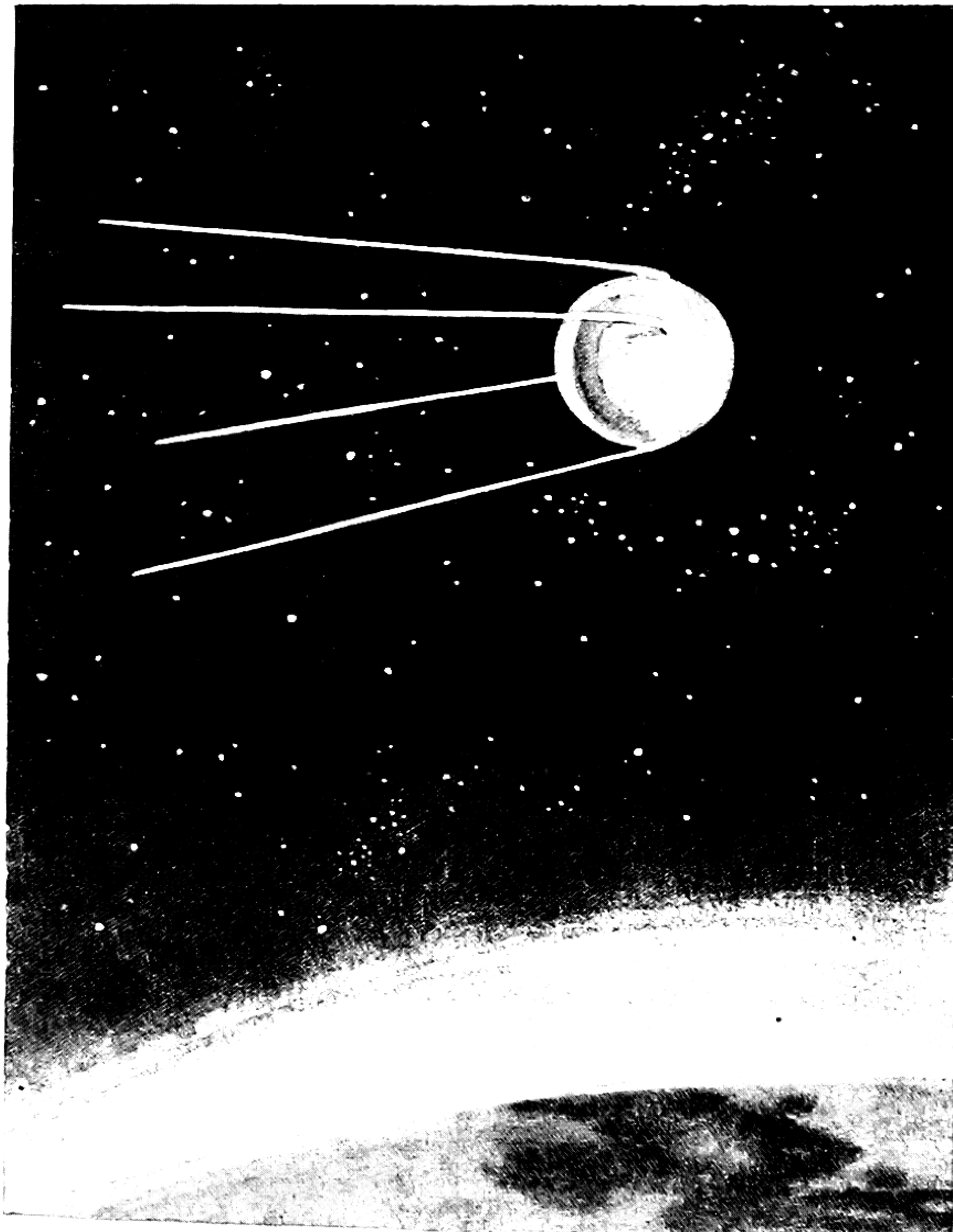
Heinz Kaminski, Director of Bochum Observatory in West Germany, said that the Russians' achievement "could be compared to a marksman hitting the eye of a fly 10 kilometres away...."

Kaminski's comparison is a very apt one and is not in the least exaggerated. To see for yourself you must take a piece of paper and cut out a circle ten centimetres in diameter. Hang it up and then look at it from a distance of eleven metres and you will see a spot that looks as big to you as the Moon is in the sky. This was the target that the space-rocket had to hit after travelling 380,000 kilometres in 43 hours. And the shot had to be "aimed off" because at the moment the rocket was launched, the Moon, itself a moving body, was still 150,000 kilometres from the place where the space vehicle would strike it.

The accuracy of the calculation made by Soviet astronomers and the precision of the instruments guiding the rocket were really amazing: the rocket hit the Moon in the area at which it had been aimed and arrived about two minutes earlier than had been forecast. This is, indeed, the accuracy of a marksman.

If it had gone the tiniest bit out of its path the rocket would have been carried thousands of kilometres off course and would not have reached the Moon. The speed of the rocket also had to be maintained with the greatest accuracy since the increase of only a few metres a second would have carried the rocket out into the vast spaces of the solar system and it would have become another solar satellite like the first Soviet artificial planet that was launched on January 2, 1959 (you will read about this further on in the book). If it had gone just a little bit slower it would not have flown as far as the Moon but would have returned to Earth like the American rockets Pioneer I and Pioneer III.

The last stage of the multi-stage rocket weighed 1,511 kilograms



after the fuel had burned out; it housed a container of scientific instruments weighing 390.2 kilograms that separated from the carrier rocket when it went into orbit. The measurements made by the instruments were transmitted back to Earth by radio up to the moment the instrument container reached the Moon.

The space-rocket reached the Moon between the Sea of Serenity and the Sea of Tranquillity (Mare Serenitatis and Mare Tranquilitatis on your lunar map) and some observers even noted the cloud of dust raised by the rocket when it struck the Moon.

The pennant delivered to the Moon

The Soviet rocket carried pennants bearing the arms of the Soviet Union and the inscription "U.S.S.R. September 1959" to our eternal satellite. We imagine that the first explorers of the Moon will hunt for the pennants carried to the Moon by the Soviet space-rocket and will place them on top of a cairn to remind future generations of this great Soviet achievement.

THE FIRST SOVIET ARTIFICIAL EARTH SATELLITES

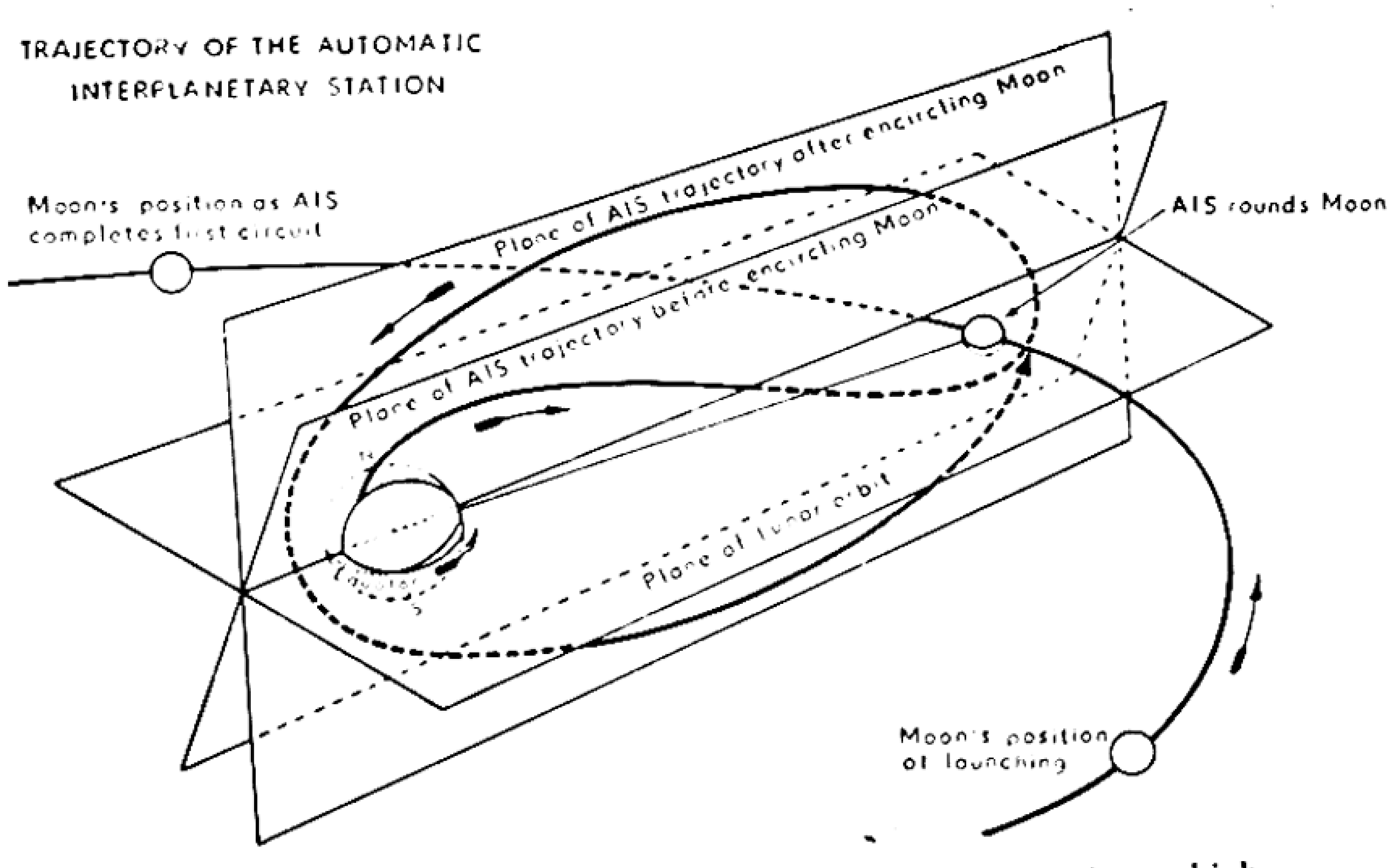
Several times in this book we have mentioned the Sputniks, the Soviet artificial Earth satellites. Now we are going to learn more about this wonderful achievement of Soviet science.

If we want to build an extra-terrestrial station we must send up hundreds of rockets each containing separate parts which must then be collected and assembled in outer space. This is a very difficult and complicated job and long preparations for it must be made; we had first to learn how to launch rockets that would revolve around the Earth and become man-made satellites of our planet. Man-made satellites were first launched in the Soviet Union.

On October 4, 1957, the first of them was launched and news of it soon spread to all countries of the world. The baby moon was everywhere given the name of Sputnik, the Russian word for satellite or fellow-traveller and it soon became known by young and old alike everywhere in the world.

The new heavenly body was very small. Its diameter was only 58 centimetres and it weighed a little more than 83 kilograms. In this small container engineers managed to house two small short-wave radio transmitters whose signals, bleep, bleep, bleep, soon became familiar to radio amateurs of all countries.

Before the world had fully recovered from its amazement and admiration the Soviet people sprang another surprise. On November 3, 1957, Sputnik II went out into space. Sputnik II was the nose section of a rocket and weighed 508 kilograms; it held a large number of measuring instruments and a special container with a dog inside it. The dog, Laika, flew to a tremendous height in outer space which showed that a living being can withstand the terrific acceleration of a rising rocket.



The flight path of the artificial interplanetary station which photographed the far side of the Moon

A little over six months after the launching of Sputnik II, on May 15, 1958, Soviet scientists sent up their third satellite, Sputnik III, which foreign journalists called a flying automobile. Sputnik III weighed 1,327 kilograms and was big enough to have held a man.

What happened to the first Sputniks?

Although the air is very rarefied at high altitudes it is still sufficient to resist the motion of the man-made moons, they gradually slow down, fall into the denser layers of the atmosphere and there burn up like meteors. This is no cause for regret, however, for the Sputniks are of great scientific value. Scientists observe them through telescopes, get radio reports from them and learn many new things about the upper layers of the atmosphere.

Each new Sputnik is sent up higher than the previous ones. The greatest height reached by the first Sputnik was 900 kilometres, Sputnik II reached 1,700 kilometres and Sputnik III, 1,880 kilometres. The higher a Sputnik flies the longer it lasts because there is less air resistance.

Sputnik I lasted about 92 days and made 1,400 revolutions around the Earth, a total distance of about 60 million kilometres. If it had flown towards Mars it would have reached that planet at the time when it is closest to the Earth. Sputnik II was in orbit for 162 days and travelled about 100 million kilometres, two-thirds of the distance from the Earth to the Sun.

Sputnik III was in flight for 691 days during which time it made 10,036 revolutions about the Earth and travelled a distance of 448 million kilometres—three times the distance from the Earth to the Sun. It ended its long and useful life on April 6, 1960.

When some dozens of artificial satellites have been launched and man has fully mastered the techniques of rocketry it will be time to set about building the first extra-terrestrial station that will open up the way to the planets of the solar system.

AROUND THE MOON

The history of science will record October 4, 1959, as a red-letter day. On that day, the second anniversary of the launching of Sputnik I, the third Soviet space-rocket set out on a journey that was to take it round the Moon and bring it back to the region of the Earth.

When the rocket went into orbit an automatic interplanetary station weighing 278.5 kilograms separated from it. This made true the dreams of Tsiolkovsky who designed such stations as long ago as the beginning of this century.

The station housed very complicated and precise instruments and batteries supplying current for them and for the radio transmitters. Solar batteries, that use the energy of the Sun to make into electricity and work for a very long time, were an important source of current supply in addition to that of the chemical batteries.

The interplanetary station differed from the Sputniks in one very important feature: the Sputniks carried radio transmitters that worked continuously, sending signals back to Earth all the time. The automatic interplanetary station is different. Its apparatus was designed to work only when orders were sent to it from Earth.

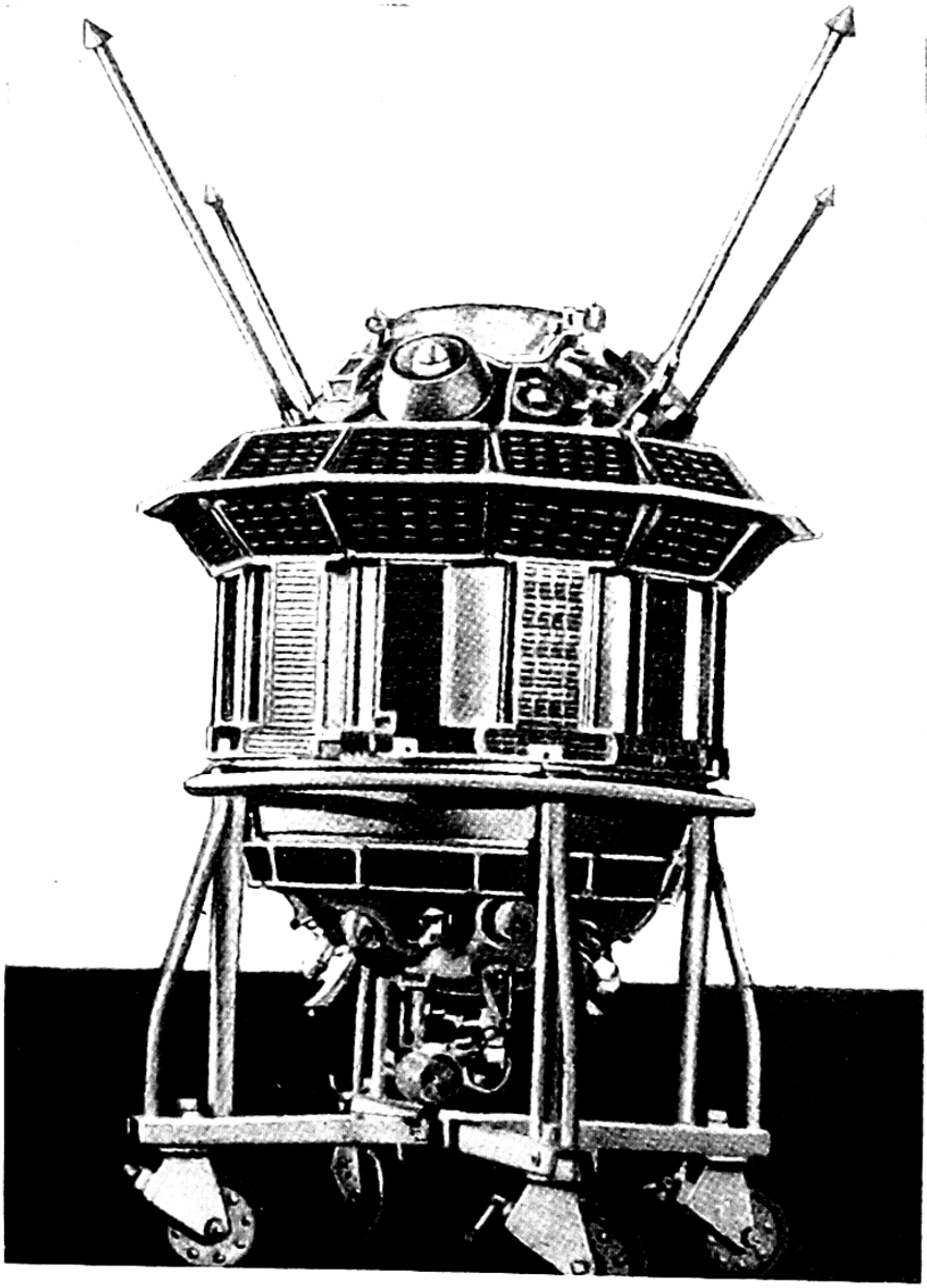
When the order was received the apparatus on the station was switched on, a radio "session" began and the observations and measurements made by the instruments were radioed back to Earth. Each session lasted one or two hours or until such time as it was ordered by Earth to stop working and wait for fresh orders which came a few days later.

We have already told you about the accuracy that was necessary to send the first rocket to the Moon. The interplanetary station had to be launched with even greater accuracy; some of the newspapers in other countries even called it "fantastic precision."

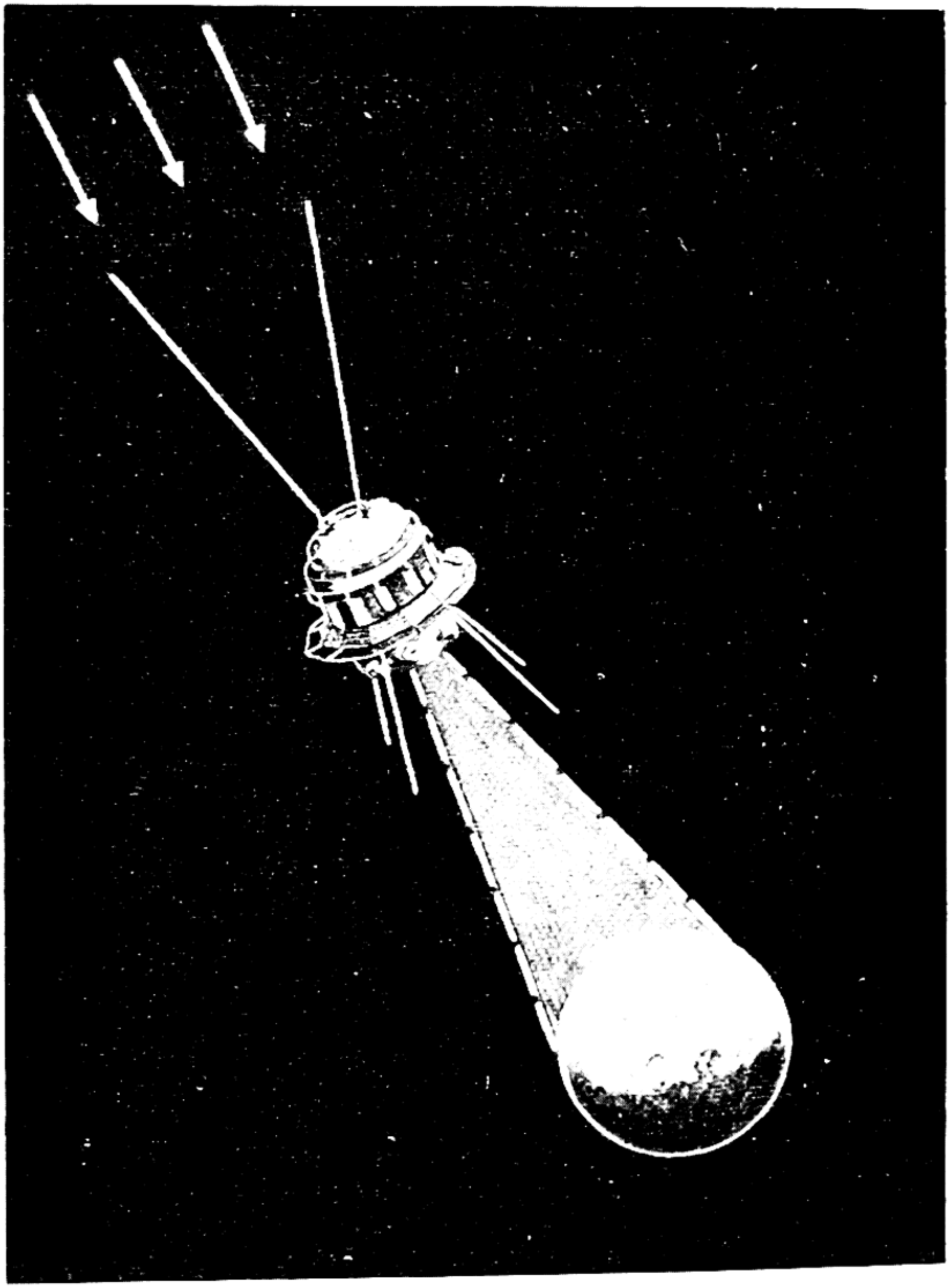
The purpose of the interplanetary station, of course, was much more far-reaching than that of earlier rockets. The station did not merely have to reach the Moon and land on it—it had to go right round the Moon and come back to somewhere near the Earth. Despite the difficulty of this programme, it was carried out, the station went into orbit exactly as planned and on October 18, 1959 at 19.50 hours (Moscow time) completed its first journey round the Earth and the Moon, a journey that had lasted about a fortnight.

Another remarkable thing was done by the station. As it passed round the Moon it photographed that side of our satellite that has never yet been seen by human eyes and transmitted the photograph back to Earth by radio.

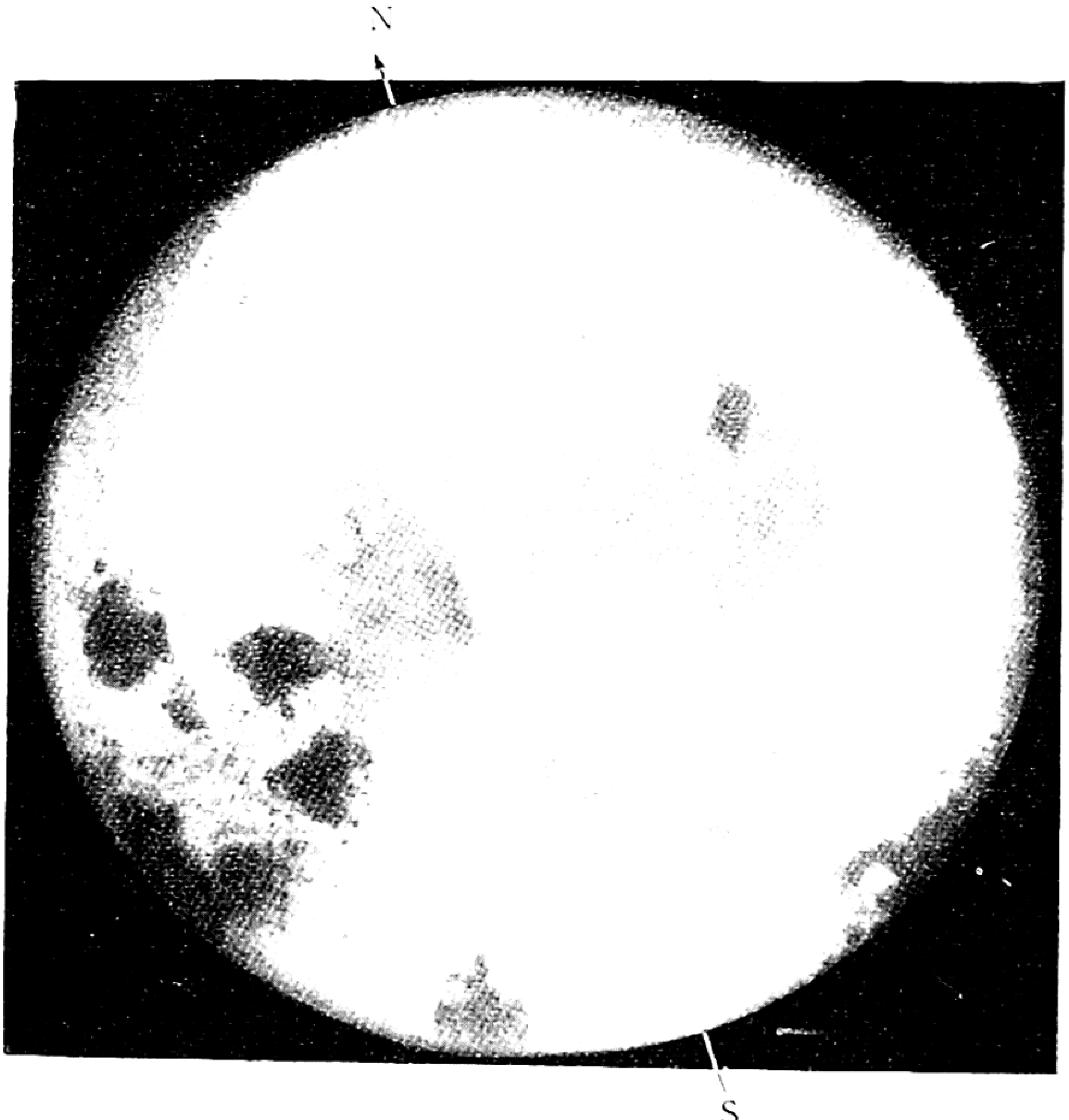
A very large number of problems had to be solved before this could be done. Video cameras had to be switched on at the moment the vehicle was passing the unseen side of the Moon. All the appa-



The Soviet automatic interplanetary station on installation trolly



Photographing the reverse side of the Moon



The reverse side of the Moon

ratus had to work in a state of free fall, that is, weightless, and it had to be protected from harmful radiations. Then the film had to be developed, fixed, dried and rolled on to another roller; it had to be kept in this state for several days and then transmitted by radio to Earth. . . .

The whole process was carried out to perfection. Special apparatus, in obedience to radio signals from Earth, stopped the vehicle's rotation at a moment when its axis lay along a line drawn from the Sun to the Moon (see drawing on p. 102), and for forty minutes

cameras photographed the side of the Moon we have never seen; photographs were taken on two scales—a small scale photo showing the whole disc and a large scale photo for surface details.

Ground stations received the images sent out by radio TV transmitters mounted on the interplanetary station (incidentally, the power used by these transmitters was one hundred-millionth part of that normally used for TV transmissions on Earth). A map of the far side of the Moon appeared before the eyes of our scientists and the mystery of the parts of the Moon never before seen was at last solved by the genius of Soviet engineers.

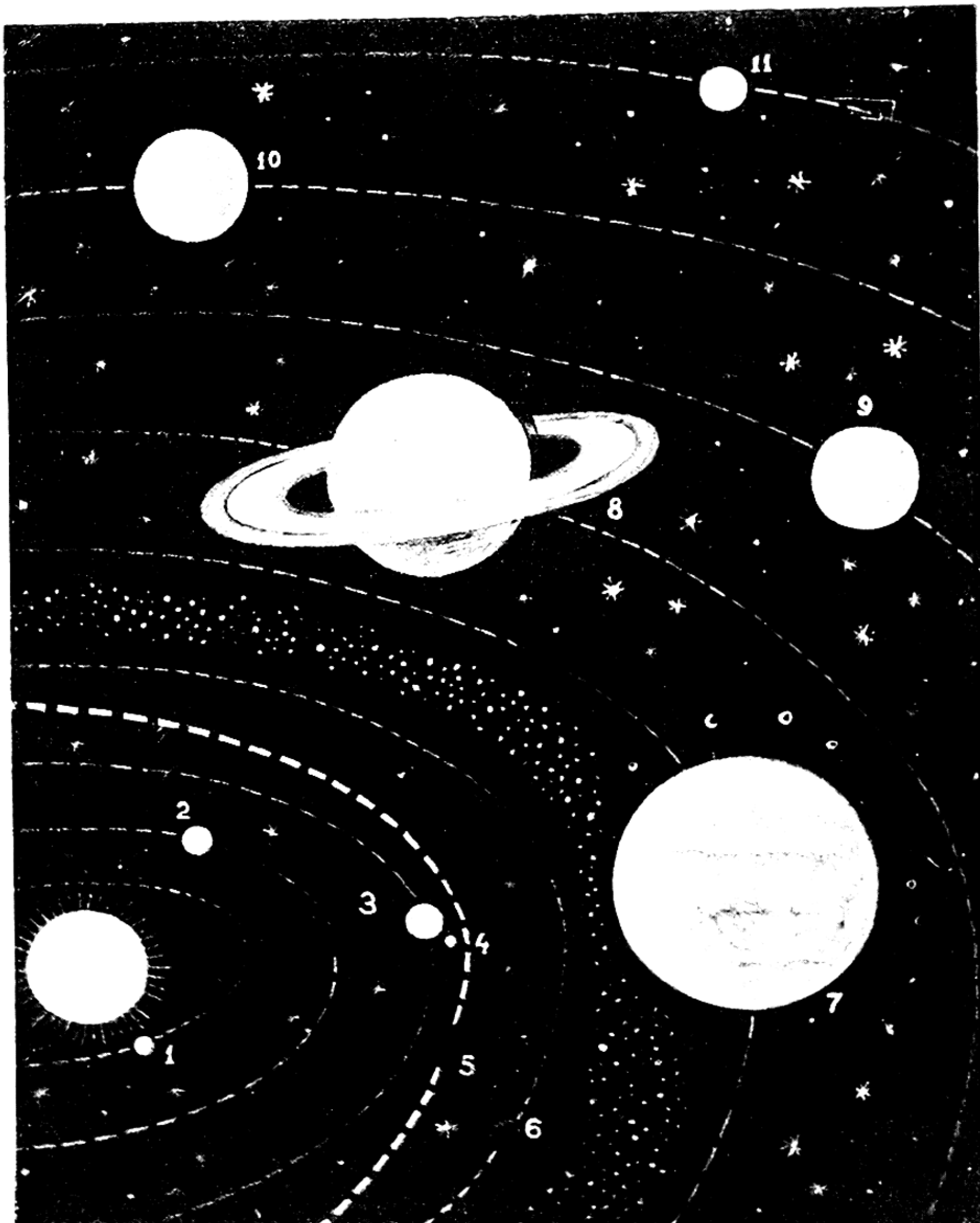
An Academy of Sciences commission gave names to some of the objects photographed. We now have on the map of the Moon a Dream Sea (commemorating the dream that came true on the day the first man-made planet, the Soviet solar satellite, was launched). There is also a Moscow Sea, dedicated to the city that devotes all its efforts to peace. The Soviet Mountains will for ever serve as a reminder of the first conquerors of outer space. Craters were named after Tsiolkovsky, Lomonosov, Joliot-Curie, Napier and scientists of other countries; they will be perpetual reminders of great men who led mankind to the heights of knowledge. . . .

During those unforgettable days in October 1959, lunar geography (selenography) made a tremendous step forward in its development. Before many more years have passed man himself will land on the far side of the Moon. And the first men who go there will have an accurate map made by the first interplanetary station and corrected by other stations that will undoubtedly follow.

SOVIET SPACESHIPS

The Soviet Union is making steady progress in the conquest of outer space and every new space-rocket sent into orbit marks a further step forward.

On May 15, 1960, Soviet scientists launched a spaceship weighing slightly more than four and a half tons (not counting the last stage of the rocket). The spaceship was equipped with a cabin weighing two and a half tons, designed to carry a man; this cabin was made to separate from the ship and continue its journey independently. On this occasion, it is true, there was no living astronaut on board, but the cabin carried a load equal to the weight of a man and all the in-



The solar system (No scale is observed in the dimensions of the Sun and the planets and the distances between them)

struments necessary for a flight. Very sensitive recording instruments showed that all conditions inside the cabin—temperature, air supply, etc.—were normal and ensured the astronaut's survival.

The spaceship travelled at a height of about 320 kilometres above the Earth in a circular orbit. This was another achievement for Soviet engineering because it is much more difficult to put a satellite into a circular than into an elliptical orbit—the instruments governing the flight of the rocket have to be much more precise. You will remember that the first Sputniks that were sent up had orbits in the form of a very elongated ellipse.

At first the spaceship completed a revolution about the Earth in 91 minutes, thus encircling the Earth almost sixteen times during the twenty-four hours.

The earlier Sputniks kept going as long as they could overcome the resistance of the air at great heights. You already know that Sputnik III kept going for nearly two years (691 days). But the spaceship was not built for such a long flight—the first astronaut, of course, will be able to take a supply of food, water and air sufficient only for a few days; the ship was built so that the cabin could be separated from the ship by a radio signal from Earth. The engineers who designed it did not expect the cabin to remain intact and return to Earth, this is something that will be attempted at the next stage in the experiments. Only when a safe return is guaranteed will a spaceship carry a man, the most valuable of all the possessions of our Soviet land.

The flight of the spaceship, however, has done a great deal to develop space travel. For several days the ship was kept under complete control and the orbit it described was exactly that which had been computed. The engineers were able to test the reliability of radio communication, the work of the solar batteries, the cabin release mechanism, and many other things.

Three months later, on August 19, a second spaceship was put into a circular orbit. This ship carried two dogs, Belka and Strelka, rats and mice, and some insects, plants, seeds and microbes. A Video camera in the spaceship's cabin recorded the behaviour of the passengers.

Although this huge spaceship weighed 4,600 kilograms it raced round the Earth eighteen times in twenty-four hours. The order was then given by radio for the ship to return to Earth, the brakes were applied, speed was reduced, and the spaceship, well protected against

heat, entered the atmosphere and landed at the appointed place Before the ship landed the cabin containing the animals separated from it and was parachuted safely to the ground.

Thus, for the first time in human history living creatures returned to Earth from outer space. Three other spaceships were launched soon after, and these also provided scientists with much new and valuable information. All the instruments and apparatus required to ensure the safety of man in space were finally tested in these flights.

LUNAR ECLIPSES

From time immemorial people have been more frightened by lunar and solar eclipses than by any other celestial phenomena.

The moon is shining brightly in the sky, not the tiniest cloud is to be seen anywhere near it. Suddenly a dark shadow begins to move across the face of the Moon and nobody knows where it can have come from. It grows and grows.... Now the greater part of the Moon has disappeared.... Finally the Moon is blotted out altogether. It is true that the Moon is still there and looks like a dark-red disc, but it does not shine any more.

The eclipse of the Moon is due to a shadow cast on it by the Earth. If the shadow cast by the Earth covers the whole face of the Moon it is called a total eclipse but if it covers only some part of the Moon then it is a partial eclipse.

A partial eclipse of the Moon does not produce such an effect on the observer as a total eclipse. That is because we often see the Moon as a thin crescent so that there is nothing unusual in it.

In the olden days people thought that a terrible monster, a dragon, devoured the Moon at times of eclipse. So strong was the belief of some peoples in the dragon that they tried to drive it away by the noise of drums and rattles. When the Moon again appeared in the sky the people were jubilant—they really believed that the noise they had made had driven away the dragon and it had abandoned its victim.

In old Russia eclipses of the Moon were regarded as omens of terrible misfortunes to come.

In 1248 a chronicler wrote: "There was an omen on the Moon: it turned blood-red and perished.... And in that summer Khan Batu approached with his army...."

And so you see, Russians in the thirteenth century believed that the eclipse of the Moon foretold the invasion of the Tartar Khan Batu.

The chronicle for 1471 said: "At midnight it was gloomy, and the Moon seemed to have blood on it, and the darkness remained for a long time and then again gradually it grew light. . . ." Every eclipse was recorded in official history as an important event in the life of the people.

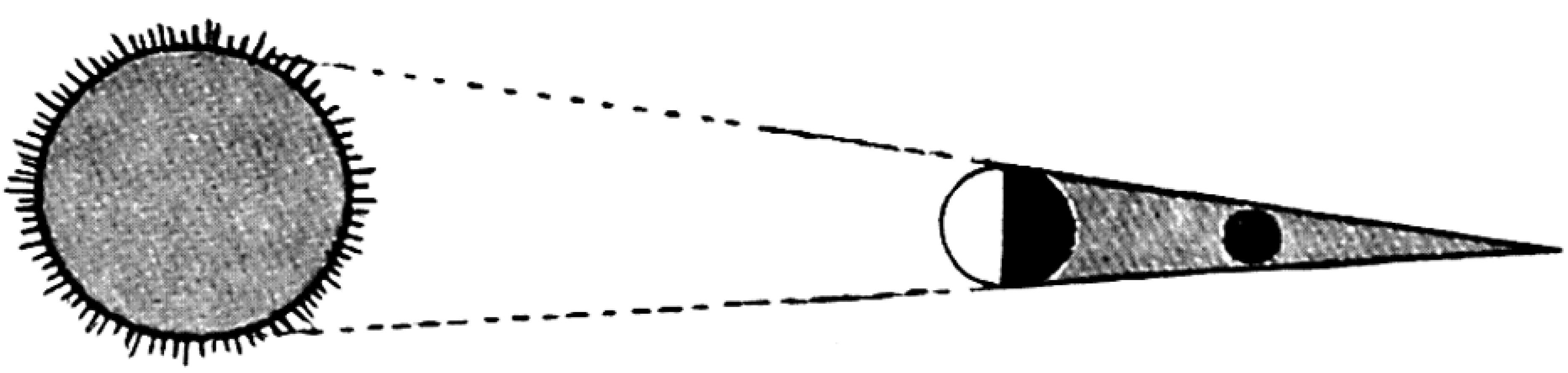
For the Moon to be in eclipse the Sun, Earth and Moon must be in one straight line with the Earth between the Sun and the Moon. This arrangement of the heavenly bodies occurs at regular intervals.

Even in the days of antiquity astronomers noticed that the eclipses of the Moon occur in the same order every 18 years, 11 days and 8 hours; it was only necessary to record the eclipses to be able to predict future eclipses with certainty.

Today it is possible to predict eclipses with very great accuracy and there is a time-table of lunar eclipses for many years to come.

THE SOLAR SYSTEM

Our Earth is a heavenly body revolving round the Sun. The Sun and all other heavenly bodies that revolve around it make up the solar system.



How a lunar eclipse occurs

The Earth is the house in which we live and the solar system is the town in which our house is situated.

Our town possesses some big buildings—Jupiter and Saturn; there are also some middle-sized buildings like our Earth, Venus and Mars; and there are also some tiny cottages, those little planets called asteroids and some very, very small ones, the meteors, that are probably the remains of planets that have been destroyed. And, lastly, there is the artificial planet, but of this we shall have more to say later on.

The houses of our Sun-city do not stand still in one place; century after century they race along invisible paths around the central luminary, the Sun. And the whole Sun-city, including the Sun itself with all its planets, races through endless space at a tremendous speed. Our Sun-city is a nomad city like all the other Sun-cities in the Universe.

And now we are going to learn something of the buildings in our Sun-city, beginning with Mercury, the nearest planet to the Sun.

MERCURY

The Romans of ancient days believed that their lives were in the hands of many gods. The father and ruler of all the gods was Jupiter and his wife was the goddess Juno. The Sun god was their son and was called Phoebus or Apollo. Venus, the daughter of Jupiter and Juno, was the goddess of beauty. The messenger of the gods was the sprightly Mercury whom the Romans depicted with wings on his feet.

People have long since ceased to believe in these gods but their names are still to be found in books on serious subjects and elderly professors pronounce them in all seriousness.

How did that happen? It is because the ancients gave the heavenly bodies the names of their gods. Jupiter, Venus and Mercury are in the sky today. Even the "shabbiest," second-rate gods and goddesses were not forgotten: astronomers named newly-discovered planets and asteroids after them.

In ancient days the study of the heavenly luminaries was connected with a false science, astrology. The astrologers said: "At the moment a child is born the position of the luminaries in the sky must be recorded—their positions in respect of each other affects the fate

of man." And the astrologers foretold his character and his whole future from these positions.

For example: if a boy was born "under the sign of Mercury," that is, when Mercury was in a certain position in the sky, the astrologers said he would become a merchant because Mercury was the patron of commerce. People born "under the sign of Mars" were to become soldiers with a cruel, blood-thirsty character. And that was only because Mars was the Roman God of war.

Seen from Mercury, the Sun is a huge flaming disc

The false science of astrology lasted for a very long time: no more than two hundred years ago astrologers still made prophecies for kings, princes and other aristocrats, and even today there are some ignorant people who believe swindlers who claim to be able to forecast the future.

Why was the planet Mercury named in honour of the swift messenger of the gods?

It is the planet nearest to the Sun and it makes a very swift revolution around that body—the journey takes it only 88 of our days. The planet Mercury's orbit is much shorter than that of the Earth, and it moves much faster.

Mercury's year, therefore, is less than a quarter of a terrestrial year. And so the Romans called the planet "Mercury" on account of its speed—the little planet was known as the "heavenly runner."

Mercury is a very small planet with a diameter of only 5,000 kilometres. Its volume is only one-twentieth of the Earth's. That means that twenty Mercuries could be made out of one Earth. Gravitation on Mercury is a quarter of that on Earth so that a man weighing sixty kilograms would weigh only fifteen on Mercury.

Observations have shown that Mercury always has the same side turned to the Sun in the same way as the Moon has only one side turned to the Earth. We already know what the Earth would be like if it were in that position. But the state of affairs on Mercury is still worse. It is much closer to the Sun and the sunlit side gets seven times more heat than the Earth.

The temperature on Mercury's sunlit side, its face, is as high as +400°C. Tin and lead melt at this temperature. If there were tin or lead mountains on Mercury they would turn into oceans of molten metal.

The hottest days in the hottest parts of our world are wonderfully cool compared with the terrific heat of Mercury on its sunny side.

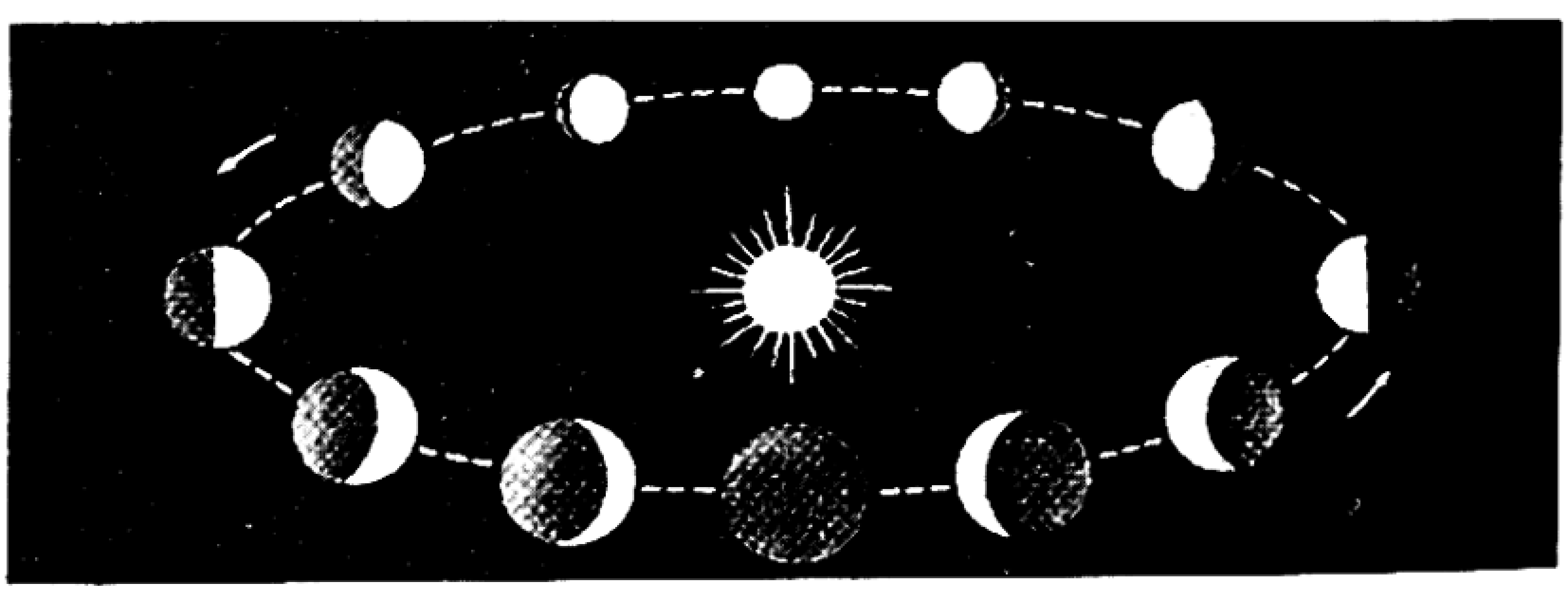
The other side of Mercury, the side that sees no sun, is terribly cold, its temperature is close to that of outer space. Scientists estimate the temperature of the cold side of Mercury at about —200° C. If there had ever been any water on Mercury the heat of the sunny side would have caused it to evaporate and strong winds would have carried the vapour to the cold side where it would immediately have turned to ice. It is far more likely, however, that there never was any water on Mercury since it could not have formed at such high temperatures.

Apparently Mercury has no atmosphere. Naturally, under these conditions there can be no life on that planet.

Mercury has no satellites.

The planet goes through phases like our Moon but they can only be seen through a telescope.

When the Earth and Mercury are on the same side of the Sun its cold, unlit side is turned towards us and we cannot see it (see picture below).



The phases of Mercury or Venus as seen from the Earth

Mercury can be seen in full when it and the Earth are on opposite sides of the Sun; at that time, however, it is very far away from

us. The best view we get of Mercury is when it is in its first or last quarter, when it is to the right or left of the Earth. In general it is very difficult to observe Mercury because it is so close to the Sun that the Sun's rays obscure it.

VENUS

After sunset on some evenings a very bright star appears in the western part of the sky. This is the Evening Star and it first appears in the sky long before darkness sets in. Then it moves lower and lower and finally disappears over the horizon, following in the wake of the Sun.

Some mornings, before sunrise, there is a very bright star in the eastern part of the sky; it remains there longer than any other star. All the other stars disappear but the Morning Star still remains. It is only when the Sun appears over the horizon that the star is dimmed by its rays.

Go out of doors in the evening, about half an hour after sunset and look for the Evening Star in the western sky. When you have found it watch it slowly sink toward the horizon in the west.

If the Evening Star is not there in the west, ask somebody to wake you about half an hour before sunrise and go outside and look towards the east; perhaps you will see a very bright star there.

What is this mystery? Actually there is no mystery at all, for there are not two stars, the Morning and Evening Stars, but one that can sometimes be seen in the morning and at others in the evening; there are times when it does not appear in the sky at all. And it is quite wrong to call this bright luminary a star—it is no star but the planet Venus. The Romans gave it this name in honour of the goddess of beauty.

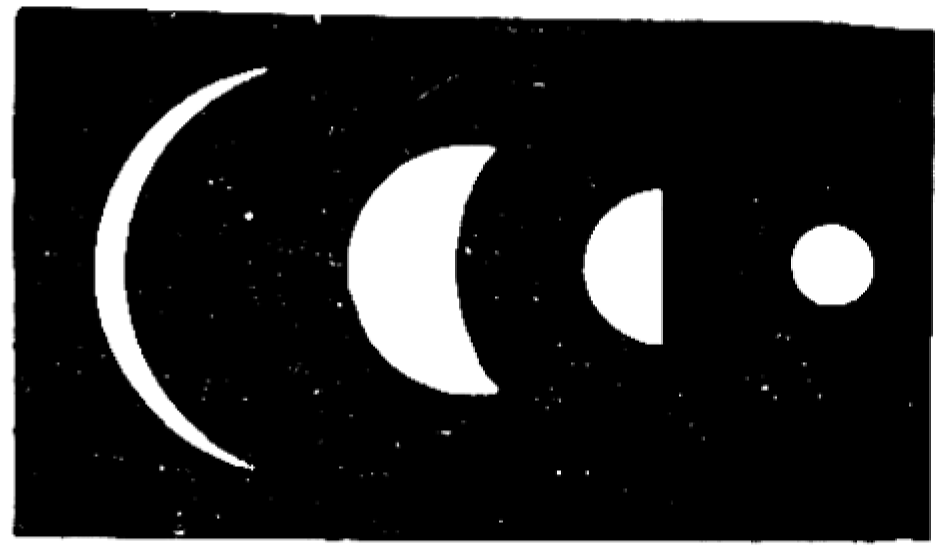
The planet Venus really is very beautiful. It shines with a soft white light and there is no star or planet that can rival it in brilliance.

"It must be a very big planet if it shines so brightly," you may think.

But that is not so, Venus is no bigger than our own planet. Venus and the Earth are sometimes called the heavenly twins.

Venus looks very bright to us because it is our nearest neighbour in space, with the exception of the Moon, of course. Venus can

approach to within 42 million kilometres of the Earth and this distance, compared with that between the Earth and Pluto, is very small indeed.



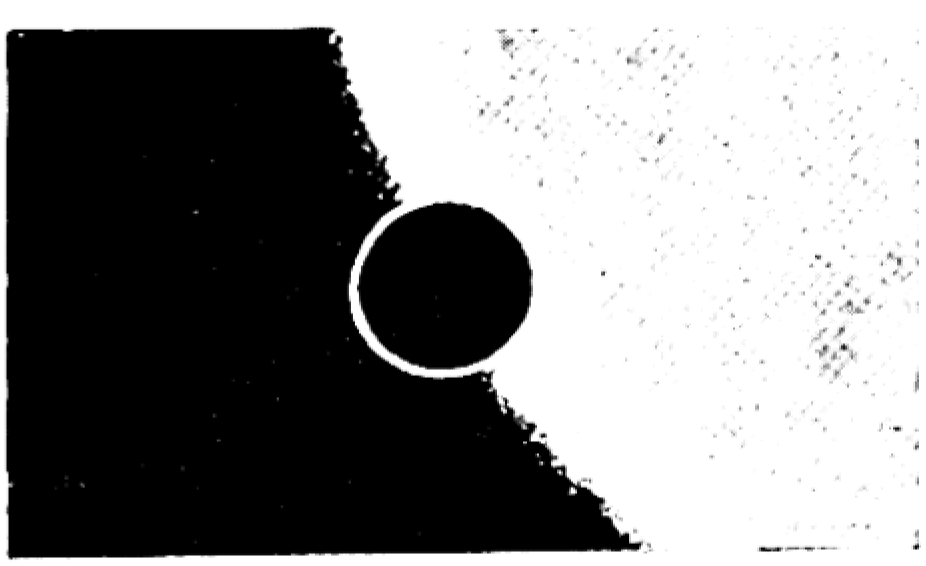
Venus as seen in different positions in relation to the Earth

The year on Venus is much shorter than that on Earth, it lasts only 225 days, seven and a half terrestrial months. Venus also has phases, like the Moon and Mercury.

If you look at Venus through a good telescope you will see some shapeless patches on its surface, some light and some dark; they look very much like clouds. Since clouds can only float in an atmosphere Venus must have an atmosphere and one that is very high and dense.

The first to realize that Venus has an atmosphere was the Russian scientist, Mikhail Lomonosov. He discovered it in 1761, almost two hundred years ago, when he observed a very rare phenomenon —the passage of Venus across the Sun's disc. This only occurs when Venus is in a direct line between the Earth and the Sun; the daylight side of the planet is then turned towards the Sun and its dark side to us, so that it looks like a tiny black circle as it passes the bright face of the Sun.

At the moment when Venus was approaching the Sun, Lomonosov noticed a faintly glowing ring around it. He assumed correctly that this ring is Venus' atmosphere lit up by the Sun's rays passing through it.



Venus crossing the Sun's disc

Other astronomers who were watching Venus at the same time as Lomonosov were not so observant.

They noticed the ring of light but did not realize what it was and merely complained that the aura around Venus prevented them from noting the exact time

when the edge of the planet reached the edge of the Sun's disc.

But Lomonosov wrote: "... the planet Venus is obviously surrounded by an atmosphere of air, the same as (if not greater than) that which lies around our terrestrial globe."

Such a clear understanding on the part of Lomonosov is really astonishing for he did not watch the planet's motion from an observatory but through a home-made telescope pointed out of the window of his house!

The passage of Venus across the Sun's disc occurs very rarely. The last passage occurred in 1882 and the next will be in 2004, so perhaps the readers of this book, who by then will be quite old, will be able to direct their telescopes to the Sun in that year....

Science has made great progress since the days of Lomonosov. Scientists today not only know which planets have an atmosphere but are also able to say what gases that atmosphere contains.

Scientists know that the atmosphere of Venus contains nitrogen but they still do not know whether there is oxygen there or not. You will understand, of course, what this means. It means that there is no vegetation on Venus that gives off oxygen into the atmosphere or that there is still very little of it. And it is not at all surprising that there is very little plant life there as you will see in a moment.

Mikhail Lomonosov (1711-1765)

Observations show that the day on Venus lasts as long as 20 to 24 of our terrestrial days (the exact figure has not been determined as it is a matter of great difficulty). The day and the night on Venus are each from 10 to 12 days and nights on Earth, that is about 250-300 hours. And Venus is much closer

to the Sun than our Earth; it gets twice as much heat and light from the Sun as we do.

You remember from our journey to the Moon that the difference in day and night temperature there is very great because the day and night are both 354 hours long. Now Venus is much closer to the Sun than the Moon is, so the difference between the day and night temperatures would be even greater if there were no atmosphere. The thick clouds that float in the atmosphere during the day protect the surface of the planet from the burning rays of the Sun and at night the atmosphere prevents the warmth escaping quickly into space.

Nevertheless, the daytime temperature on Venus would seem much too high for us: it reaches $+100^\circ$ C. This means that the oceans of Venus, and scientists assure us that there are oceans on that planet, would be as hot in the daytime as boiling water is on Earth.

Astronomers have measured the temperature of the cloud layer on the night side of Venus and found that it is -23° C. This is quite bearable: in some places 23-degree frosts are not considered very severe.

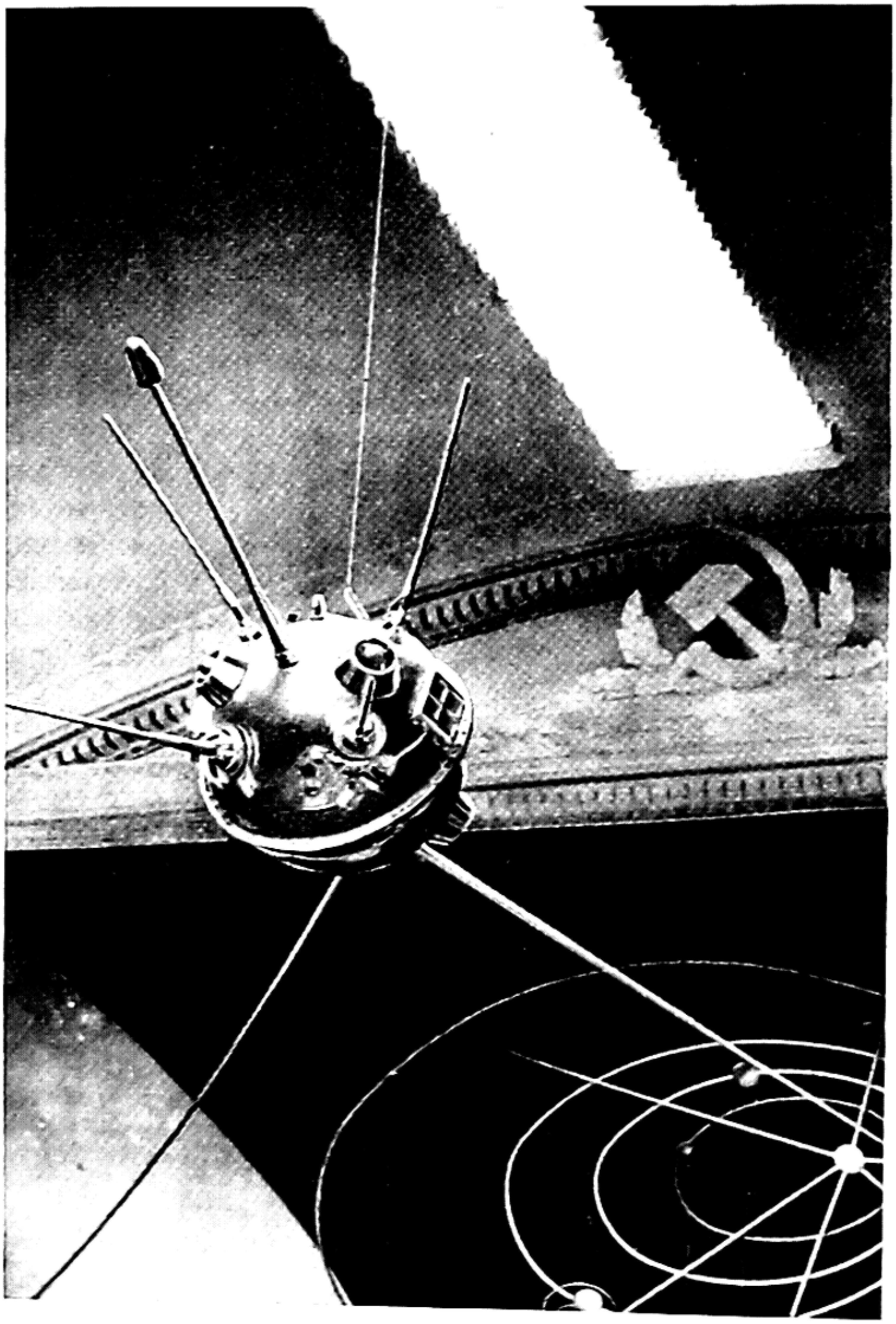
But you can see that conditions are not very suitable for the existence of plant life on Venus. Despite that, however, it cannot be said with certainty that there is no plant life there. There are water plants on Earth that live in hot springs. And our terrestrial plants have learned to withstand severe frosts. It is, therefore, quite possible that there is vegetation on Venus, but not very much of it and it did not come into existence a very long time ago and has not been able to give off sufficient quantities of oxygen for scientists to detect it with their instruments.

It is possible that life will develop on Venus in the same way as it developed on Earth.

THE FIRST MAN-MADE PLANET

At 8 o'clock in the evening on January 2, 1959, Soviet engineers launched a gigantic multi-stage rocket that raced upwards through the darkness of night cutting its way through the dense terrestrial atmosphere.

An event had occurred that mankind will never forget, an event that the world's greatest thinkers had dreamed of for centuries. On



The Soviet artificial planet "Mechta" (Dream)

that dark night the first interplanetary vehicle plunged into outer space. It did not yet carry a man on board, its motion was controlled by intricate machines that had been designed by Soviet scientists and built by Soviet workers. So great was the precision of those machines that the space-rocket followed the path allotted to it, passed the Moon at a pre-arranged point and flew on to become a satellite of the Sun and take its place as an equal member of the family of planets. Admiring humanity again applauded the deathless scientific exploit of the Soviet people.

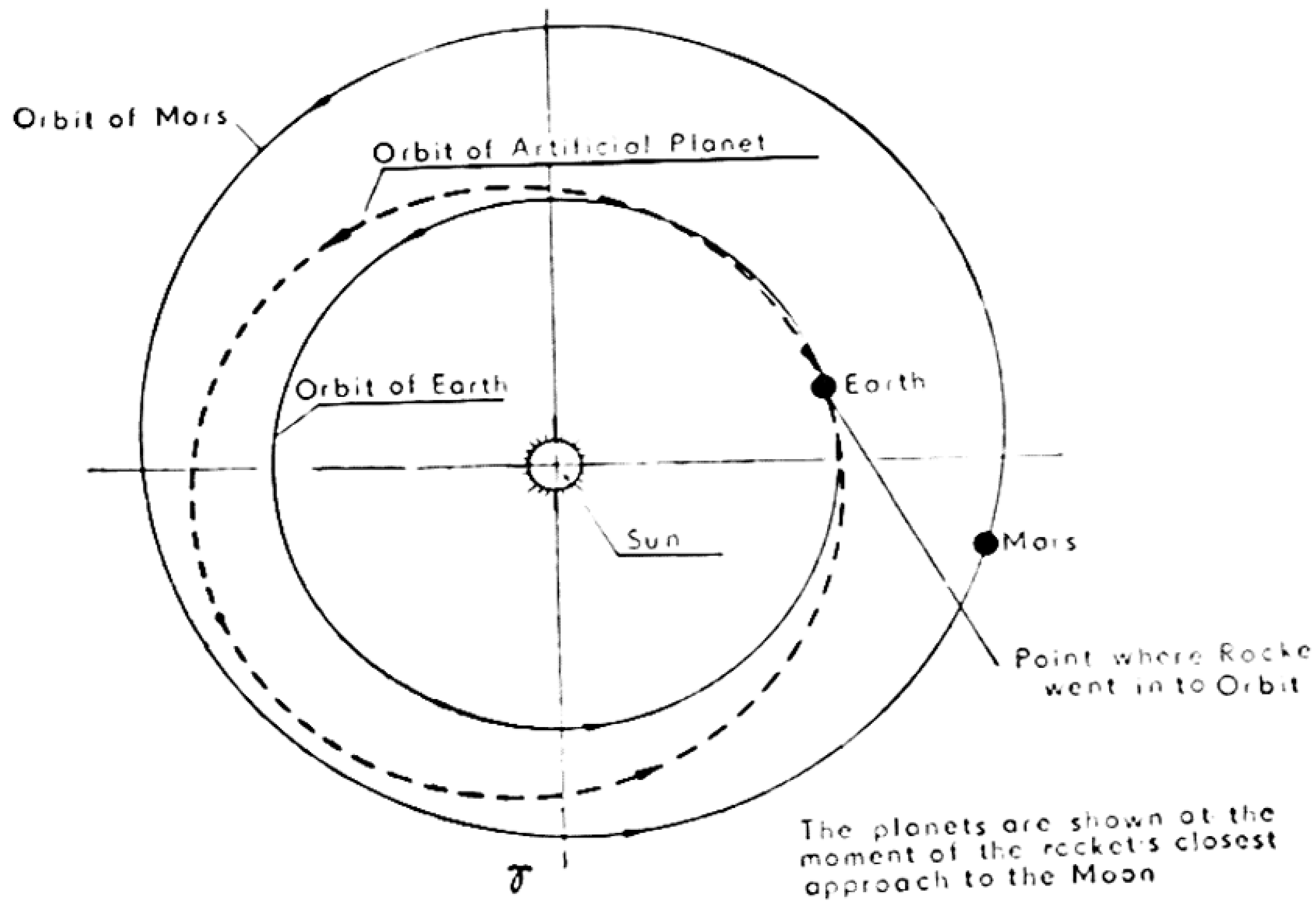
The new planet is not very big, it has a mass of only 1,472 kilograms which is millions and millions of times smaller than the Earth. This child of the Earth, however, differs from all other heavenly bodies in the solar system because people gave it the ability to talk about its journey from the Earth to the Moon. Clever, very sensitive machines were able to report through short-wave radio transmitters everything met with on the way. Soviet scientists have analysed these reports and learned how many meteoric particles are racing through space, how many rarefied gases there are up there. what streams of energy are carried to us from the Sun and many other things.

The first space-rocket passed the nearest point to the Moon at 5.59 a.m. on January 4 (Moscow time). At this moment it was between 5,000 and 6,000 kilometres from the Moon's surface, a distance equal to about one and a half lunar diameters.

The rocket's flight from the Earth to the Moon took 34 hours, but scientists have spent many months of intensive study analysing the reports sent back by clever instruments on board the rocket.

You may perhaps want to know why a rocket that left the Earth at the velocity of escape, 11.2 kilometres a second or about 40,000 kilometres an hour, took 34 hours to make a journey of 370,000 kilometres instead of doing it in a little over 9 hours?

There is a very important circumstance that has to be considered —the Earth's gravitation. Imagine an experiment of this sort. A heavy ball fastened to a thin elastic is fired from a toy cannon. The ball flies out of the muzzle but the elastic holds it back and slows down its flight. If the motion of the ball is fast enough to break the elastic it will fly farther; if the elastic does not break it will pull the ball back.



Orbit of first artificial planet

The Earth's gravitation may be likened to an unseen elastic thread that gradually slows down the rocket's motion, and if it becomes too slow that unseen elastic will pull it back to Earth. This is what happened to four rockets sent out in the direction of the Moon by the Americans in 1958: not one of them reached its goal, they all came back to Earth because they were unable to break the chains of gravity (the elastic).

Our space-rocket was the only one that broke these chains and entered its allotted orbit around the Sun. The Earth's gravitation, nevertheless, affected it and caused it to lose speed. But the velocity was still sufficient to keep the rocket either from falling back to Earth or from falling on to the Moon that also pulled at it, and to keep it going into outer space.

And what happened after this to the rocket that ran away from the Earth, and then ran away from the Moon?

As we have said, it went into orbit about the Sun and the position and dimensions of the orbit were published on January 4, 1959.

Scientists were able to make calculations in such a short time by using electronic computing machines, one of the greatest inventions of the last few years. These machines can make calculations in a few hours that would take dozens of skilled mathematicians many months.

What is the orbit of the new planet like?

It is a somewhat elongated circle and the Sun is 25.8 million kilometres to one side of its centre. In its motion in this orbit the man-made planet reached its perihelion, the point nearest the Sun (146 million kilometres from it), on January 14, 1959. It reached its aphelion, the point farthest from the Sun (197 million kilometres), at the beginning of September 1959.

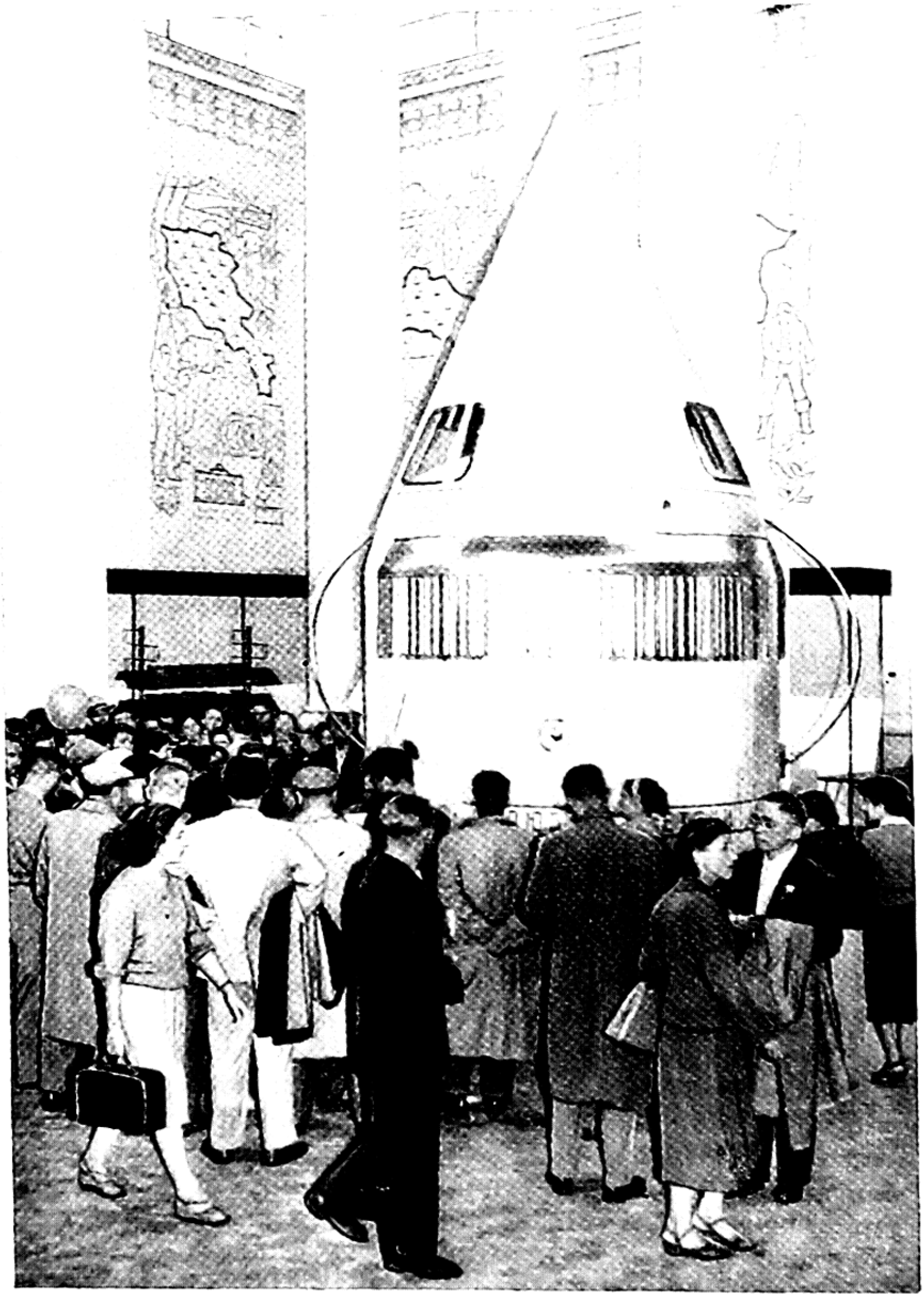
The new planet's year, that is, the time taken for one revolution about the Sun, is 15 months, a quarter longer than our year.

The average distance between the man-made planet and the Sun is 172 million kilometres which is 22 million kilometres greater than the average distance of the Earth from the Sun. The first artificial planet of the solar system has its orbit between those of the Earth and Mars (see drawing on page 117). It follows the Earth's orbit for a very short distance and then moves farther out into space and draws closer to Mars; at times it may be only 15 million kilometres from Mars which is about a quarter of the shortest distance between Earth and Mars.

The velocity of the new planet in its orbit is 32 kilometres a second and in one year the planet travels about one thousand million kilometres.

And now you will want to know how the planet acquired such tremendous velocity if it left the Earth at a speed of 11.2 kilometres a second and passed the Moon at a speed of only 2.45 kilometres a second. This can be easily explained: when the rocket was standing on the launching pad it was already moving through space at a velocity of 30 kilometres a second. Don't look so surprised: you and I and everything on Earth are all racing round the Sun at a speed of 30 kilometres a second, more than 100,000 kilometres an hour, although we never notice it.

And there is one thing you must always remember: all the velocities mentioned in this book—the first and second cosmic velocities, the velocity of the rocket near the Moon—are all given with reference to the centre of the Earth, our own Earth to which we



Last stage of Soviet space-rocket that launched the first man-made planet

are so firmly bound that even when we leave it we retain its velocity in respect of the Sun.

The laws of mechanics tell us that velocities having the same direction are added. A river steamer goes downstream at a speed of 30 kilometres an hour; you run along its deck at a speed of 10 kilometres an hour and your speed or velocity with reference to any point on the bank will be 40 kilometres an hour.

The velocity of the rocket itself when it went into orbit around the Sun was 2 kilometres a second. To this we must add the velocity in respect of the Sun, 30 kilometres a second, that it had at the moment it left the Earth and which it retained; thus we get 32 kilometres a second.

The first man-made planet carries pennants with the proud inscription *Union of Soviet Socialist Republics. January 1959*. It will carry these pennants thousands and thousands of millions of years around its orbit unless some cosmic catastrophe occurs, such as a collision with a big meteorite or unless the people of the future chase it in a spaceship to bring it back to Earth as a magnificent memorial to this wonderful achievement of the Soviet people in the struggle to conquer space.

The creation of the man-made planet was most convincing proof of the correctness of the theories of Copernicus, Galileo and Giordano Bruno.

The first artificial planet was not alone for long; somewhat later United States engineers put two more man-made planets, smaller than the Soviet planet, it is true, into orbit round the Sun.

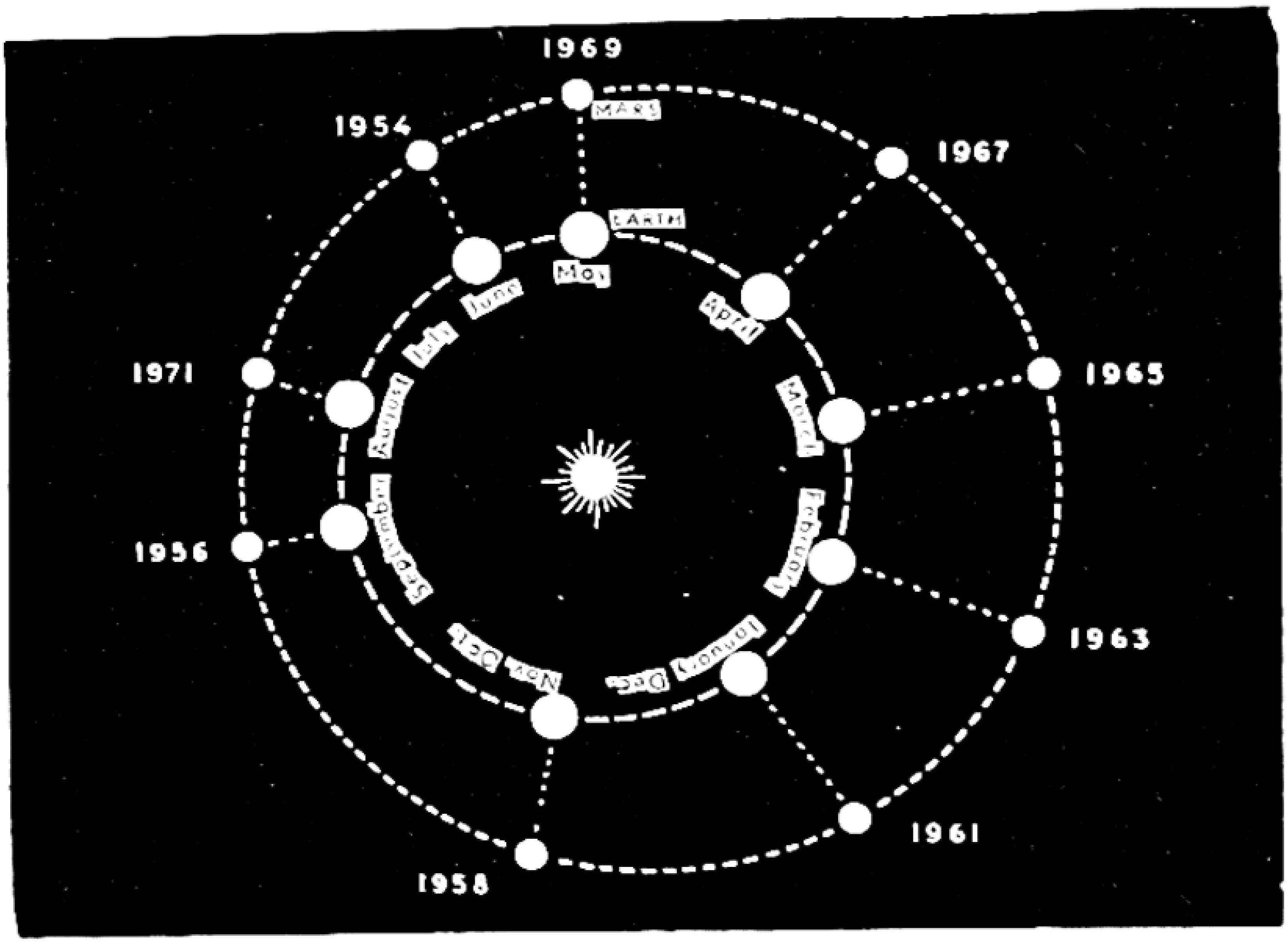
MARS

There was one planet that put fear into the people of antiquity; it seemed like the red eye of a mighty god that looked down angrily at the distant Earth. The Romans gave this red luminary the name of Mars, the god of war.

The average distance between Mars and the Sun is 228 million kilometres, half as far again as the distance from the Earth to the Sun. To make it easier to measure great distances scientists call the distance from the Earth to the Sun—150 million kilometres—

an astronomic unit. The distance from Mars to the Sun, therefore, is one and a half astronomic units.

When it is most convenient to observe Mars? Obviously when the two planets are on the same side of the Sun. When Earth and Mars are in this position it is said that Mars is in opposition. This occurs once in every two years. When Mars is in opposition it approaches to within 70-100 million kilometres of the Earth.



Mars in opposition, from 1954 to 1971

A so-called great opposition takes place every fifteen to seventeen years. At such times Mars and the Earth come closest to each other, the distance between them being only 55 million kilometres.

One such great opposition of Mars was observed in 1956 when the planet again attracted the attention of astronomers.

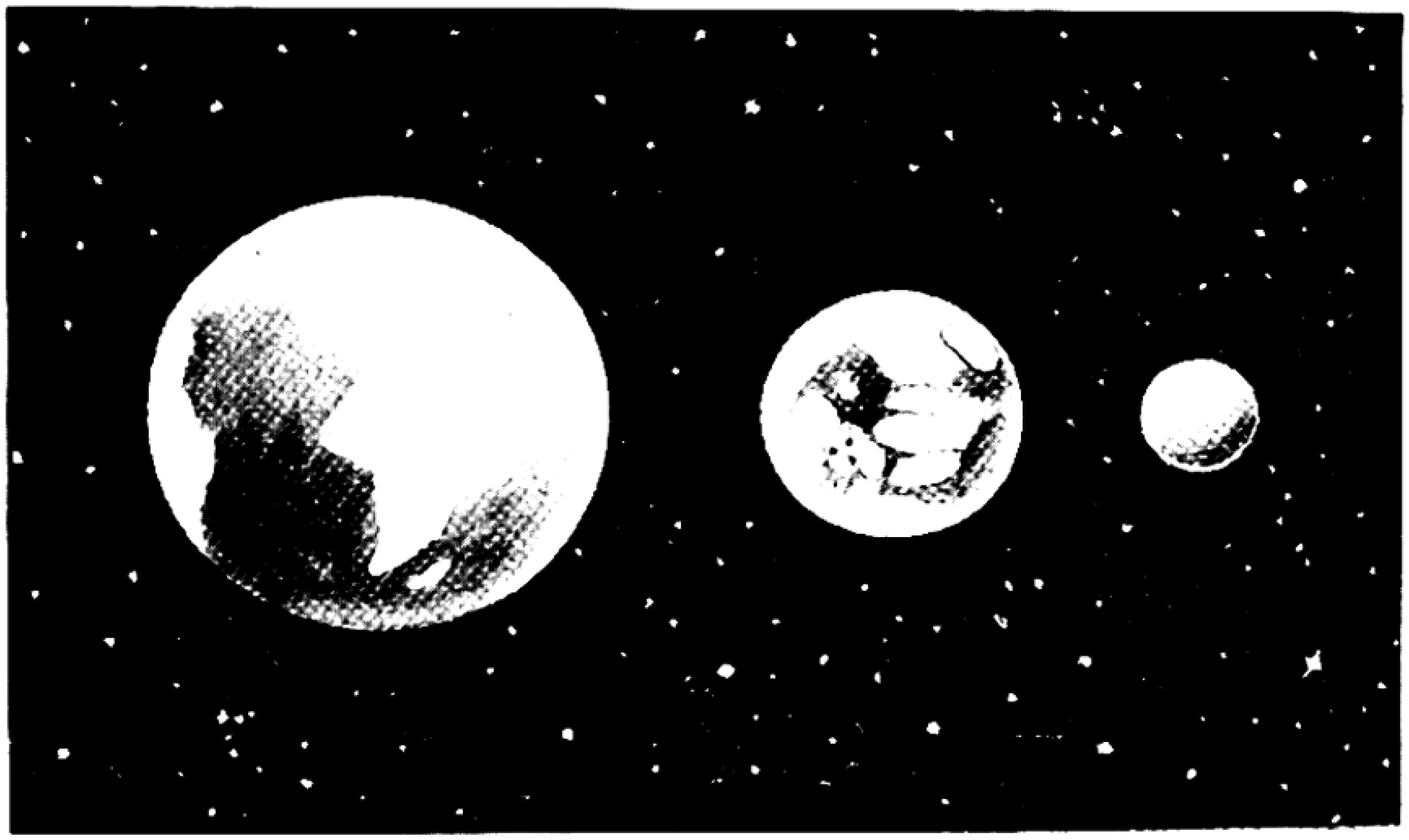
At times of its opposition Mars is one of the brightest heavenly bodies.

It is very difficult to observe Mars when that planet and the Earth are on opposite sides of the Sun. At such times the distance between them is as much as 400 million kilometres. Obviously there

are but few astronomers who make observations when it is so far away.

Mars is a small planet with a diameter of only 6,800 kilometres, twice the diameter of the Moon. Its volume is little more than one-seventh of that of the Earth.

On page 123 there is a drawing of Mars made by the French astronomer Antoniadi in 1909. The white patch at the edge of the



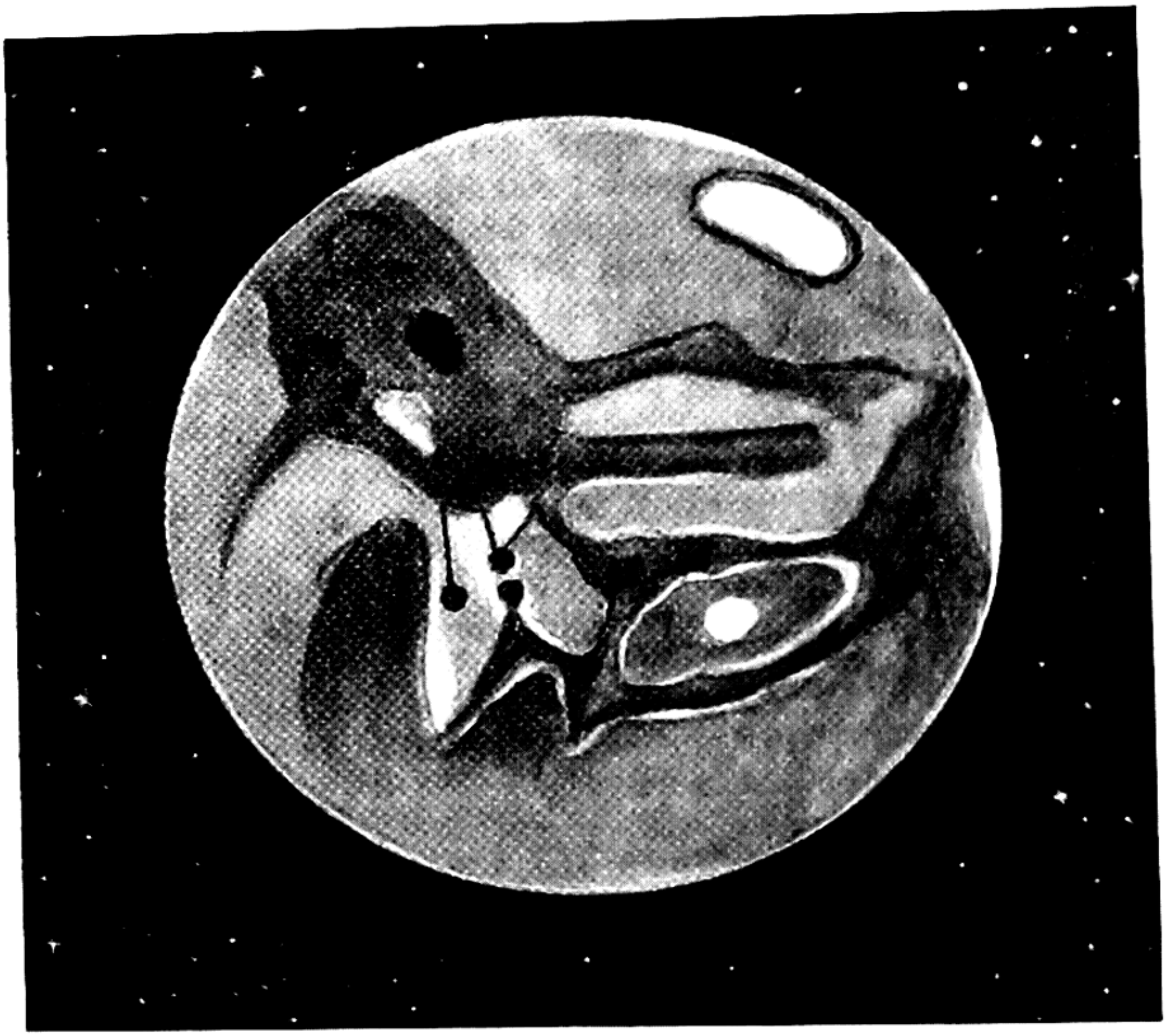
Comparative sizes of the Earth, Mars and the Moon

planet is Mars' polar cap, its covering of snow. The dark patches and stripes are called the Martian seas; the extensive greyish patches are dry land.

The study of Mars has a very interesting history.

Giovanni Schiaparelli (1835-1910), an Italian astronomer, made a detailed study of Mars for many years. In 1877, when Mars was in its great opposition, Schiaparelli observed the planet every night if weather permitted. He drew a detailed map of Mars such as no other astronomer had ever made.

The first thing Schiaparelli noticed on Mars was the dark patches. From a distance water always looks darker than land and so he called these dark patches the Martian seas. He then noticed a num-



Antoniadi's drawing of Mars

ber of thin black lines between these seas which seemed to connect them. Schiaparelli called these lines *canali* because the Italian word *canalo* means channel or strait.

The amazement of the whole world was expressed with great clamour:

"The Italian Schiaparelli has discovered canals on Mars! Canals can only be dug by people or by some reasoning beings! And what machines they must have because even we, the inhabitants of the Earth, are unable to cover our planet with a whole network of canals like the Martians have; the Martian canals must be dozens, even hundreds of kilometres wide if they can be seen through a telescope!"

Newspapers and magazines published countless articles about Mars and its inhabitants. Writers got busy writing novels about Martians. Hotheads proposed getting in touch with the Martians immediately. Some of them thought of using huge mirrors to send up light signals. Others suggested making geometric designs on the extensive plains of Siberia so that the Martians would know that there are reasoning beings living on Earth. Since the lines of these designs would have to be several hundred kilometres long and twenty or thirty kilometres wide (only if they were of such dimensions would the Martians be able to see them in a telescope) it was further suggested that they be made of strips of wheat—in the Martian telescopes the lines of golden wheat would be clearly visible against a background of black earth.

Communication with the Martians would have cost a huge sum of money and for this reason nobody even tried to begin. But the astronomers of the whole world began to make a more energetic study of the Martian canals.

It was known that in 1909 there would be a great opposition and it was assumed that the question of the Martian canals would be settled in one way or another.

The American astronomer Lowell even built a special observatory to observe Mars on a plateau in the Arizona Desert. The air there is very clear and observation is not hampered by the smoke and soot of big cities. A special telescope was obtained for this observatory; it was very powerful and had a lens 66 centimetres in diameter.

The year 1909 came and the telescopes of the whole world were directed towards Mars like giant cannon. Then began a dispute between the Arizona astronomers and scientists of the rest of the world. For some time the Pulkovo astronomers were the only ones to keep out of the discussion.

Lowell and his friends asserted that there are canals on Mars. They are not always visible, they appear in the field of vision gradually as the polar snows melt. This would mean that they filled up with water at such times.

According to the Arizona observations the water in the Martian canals flowed from north to south in the spring and from south to north in the autumn.

Since water cannot flow by the force of gravity first in one direction

and then in the opposite direction, Lowell and his supporters believed that the water was driven into the canals by huge pumps. Pumps could only be built by reasoning beings, by people that possessed a high degree of engineering skill.

"And this," said Lowell, "is further proof that the Martians exist!"

The overwhelming majority of the world's astronomers, among them very experienced observers, announced that they did not see any canals on Mars.

The opponents of the canal theory said that they were an optical illusion.

"Draw some patches and spots in no particular order on a sheet of paper," they said, "and then look at it from some distance. The patches and spots will seem to join up in lines."

To support their views, the opponents of the canals said that they could only be observed through medium-sized telescopes: the most powerful telescopes did not show canals but irregular dark patches.

American astronomers who made use of the biggest of all telescopes at that time, the Yerkes telescope with a lens a metre in diameter, said: "Our telescope is too strong for the Martian canals!"

It is very difficult to observe the heavenly bodies through a telescope. Even experienced scientists who have been making observations for many years are sometimes mistaken and draw wrong conclusions from their observations.

What would seem to be a purely scientific dispute concerning the existence of canals on Mars is really part of the discussion on whether or not there is life on other planets. There were disputes on this question even at the time of the bold thinker Giordano Bruno.

The Church Court sentenced Bruno to be burned at the stake because he asserted that: "Life exists on countless planets. The life of the Universe is infinitely varied and it would be ridiculous to believe that the Earth, a tiny speck of dust in the infinite world, is the only place where reasoning beings live."

The discovery of the canals on Mars seemed to confirm the brilliant conjecture of the great genius.

It was just at this time that the Pulkovo Observatory published its observations.

Two young astronomers, Tikhov and Kalitin, had managed to photograph the Martian canals. There turned out to be very many of them—long and short, wide and narrow.

Today a detailed map of Mars has been compiled on which there are over a thousand canals varying from 2-3 to 300 kilometres in width. Some of the canals empty into round dark patches that have been called lakes or oases.

Modern astronomers, however, do not believe that the canals are artificial engineering works. Various suggestions as to their nature have been put forward.

Some scientists believe that they are the beds of dried-up rivers. Others think they are cracks in the dried-up earth, something like colossal gullies.

According to a third school of thought the canals are strips of damp earth covered with dense vegetation that is darker than the surrounding landscape.

This third assumption is probably the most likely. During the Martian summer the canals have a dark green hue and in autumn they are lighter in colour. It is because of this change in the colour of the canals and seas (for the Martian seas also change their colour according to the season of the year) that astronomers assume the existence of vegetation on Mars.

Some Soviet astronomers think that there are some plants on Mars which lose their leaves in winter like our oaks and birches, and that others are evergreen like our conifers.

The Martian seas are probably extensive marshes covered with green vegetation.

Mars owes its reddish hue to the colour of the soil. This is the colour of deserts of clay and sand on Earth. The greater part of Mars consists of dry land and it is safe to assume that deserts occupy a very considerable area of it.

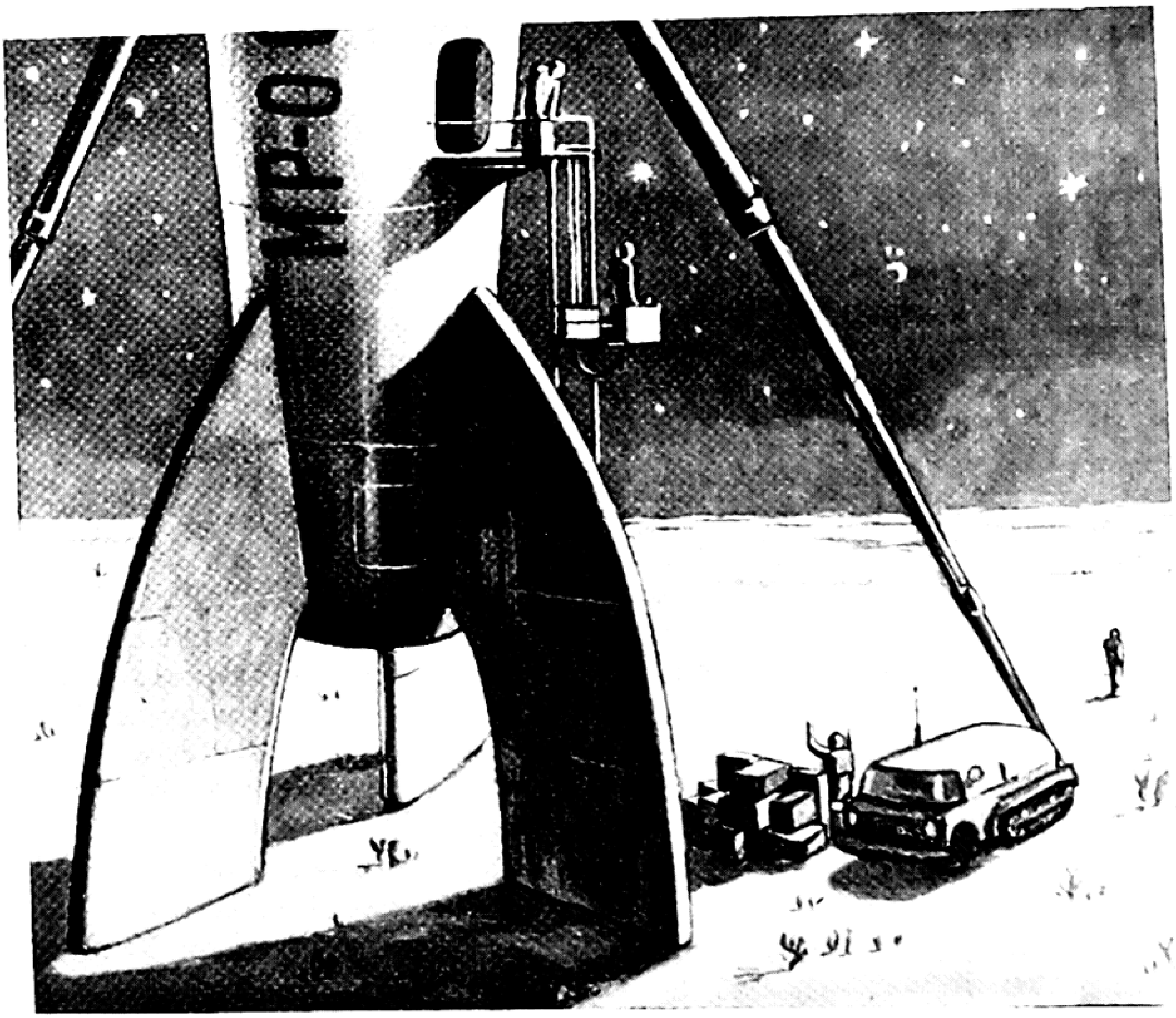
Mars has an atmosphere but it is very rarefied. Atmospheric pressure on that planet is the same as that found in the Earth's atmosphere at a height of 18 kilometres. A man on the surface of Mars would feel as though he were in the open basket of a balloon that had risen to a tremendous height. Our high-altitude balloons are fitted with hermetically sealed cabins, and the first interplanetary expedition that reaches Mars will have to wear space-suits when they leave their ship. The force of gravity on Mars is about two and a half times less than that felt on Earth, so that heavy space-suits will not be much of an encumbrance.

The climate of Mars is a severe one. The planet is one and a half

times farther from the Sun than the Earth and gets less than half the light and heat the Earth gets.

Mars, however, has a tremendous advantage over Mercury or Venus—the same advantage as the Earth—the Martian day and night, the period taken for the planet to rotate about its axis, is about the same as that of Earth; to be exact it is 24 hours 37 minutes. The days and nights are much the same as those on Earth and such short days and nights do not allow the planet to get overheated or too cold.

The most amazing thing of all is that the axis of Mars is inclined from the vertical at almost exactly the same angle as that of the Earth, so that the seasons of the year, spring, summer, autumn and



An interplanetary expedition arrives on Mars

winter, are the same. But they are much longer than the terrestrial seasons. Mars' path round the Sun, its orbit, is much longer than the Earth's and Mars travels more slowly so that one complete revolution takes 687 terrestrial days or 669 Martian days.

What is the temperature on Mars?

At its equator, the hottest part of the planet, the daytime temperature does not rise above $+20^\circ$ C; at night it drops to zero and at sunrise frosts occur up to -50° C.

In the temperate zones winter frosts bring the temperature down to -70-80° C, and at the poles the temperature drops to -100° C.

On Mars there are very sudden jumps from heat to cold in the course of a single day. If we had such a climate we should be able to go out without coats during the day but at night we should have to wear heavy fur coats and light fires in our houses.

An interesting feature of Mars is the melting of the snow caps at the poles. In winter the snowfields are from 3,000 to 4,000 kilometres in diameter, in summer they grow small and by autumn only tiny white patches are left; sometimes the snow disappears altogether. The water from the melting snow flows down to the temperate zones and brings life to the seas and canals that are soon covered with fresh vegetation. On our Earth the polar ice (in Greenland and in the Antarctic, for example) has not melted for thousands of years so that it is now tremendously thick. In the summer the ice caps melt a little at the fringes but in winter more ice is added. The rapid melting of the snow caps on Mars shows that they are not more than a few centimetres thick.

The greater part of the land on Mars consists of dry, lifeless deserts. The water has most probably seeped through the crevasses into the interior of the planet and year by year the quantity on the surface grows less and less. The atmosphere is also growing thinner because the gas particles from its upper layers are carried away into space and the gravitation of the planet, which is weaker than that of the Earth, cannot hold them back.

Mars has two small moons or satellites. They were discovered in 1877 and were named Phobos and Deimos, two Greek words that mean "fear" and "horror"—very suitable names for the satellites of the god of war!

There is everything necessary for life on Mars: water, oxygen and atmosphere, there is vegetation and alternate days and nights

and there are seasons. These are conditions that gave rise to life on Earth. It is true that conditions on Mars are more severe than on Earth but in the course of thousands of millions of years life could adapt itself to them. In the course of that long time beings as highly civilized as the people of Earth could have developed.

If that is so, you may wonder why we cannot see any Martian cities.

But perhaps the Martians also wonder why they do not see any cities on Earth. They may think that the Earth is uninhabited, for who could live in the terrific heat of that fiery planet?

Buildings would have to be of an enormous size to be seen through a telescope at a distance of a hundred million kilometres—they would have to be dozens of kilometres long and wide. It is safe to assume that if there really are Martian people it would be very difficult for them to see Moscow, Leningrad or Paris, even if the Earth's atmosphere did not prevent it.

We shall not know whether there are reasoning beings on Mars until the first interplanetary expedition arrives there.

Our talk about Mars has turned out to be much longer than those about Mercury and Venus. That is as it should be, for Mars is the most interesting planet for the people of the Earth.

THE ASTEROID BELT

Long ago astronomers noticed a considerable gap in space between Mars and Jupiter. Scientists have made calculations showing that there should be another planet in that gap.

For a long time astronomers looked for it—some came to the conclusion that it does not exist and others said that it exists but is too small to be seen in a telescope.

On the night of January 1, 1801, an astronomer discovered a tiny planet between Mars and Jupiter. He gave it the name of Ceres, the Roman goddess of growing vegetation. When the diameter of the new planet was measured it proved very small—only 800 kilometres.

"It's only a tiny crumb among the planets," said the scientists, "it's one-eightieth the size of the Moon and four thousand times smaller than the Earth. Still, it has been proved that there is something between Mars and Jupiter!"

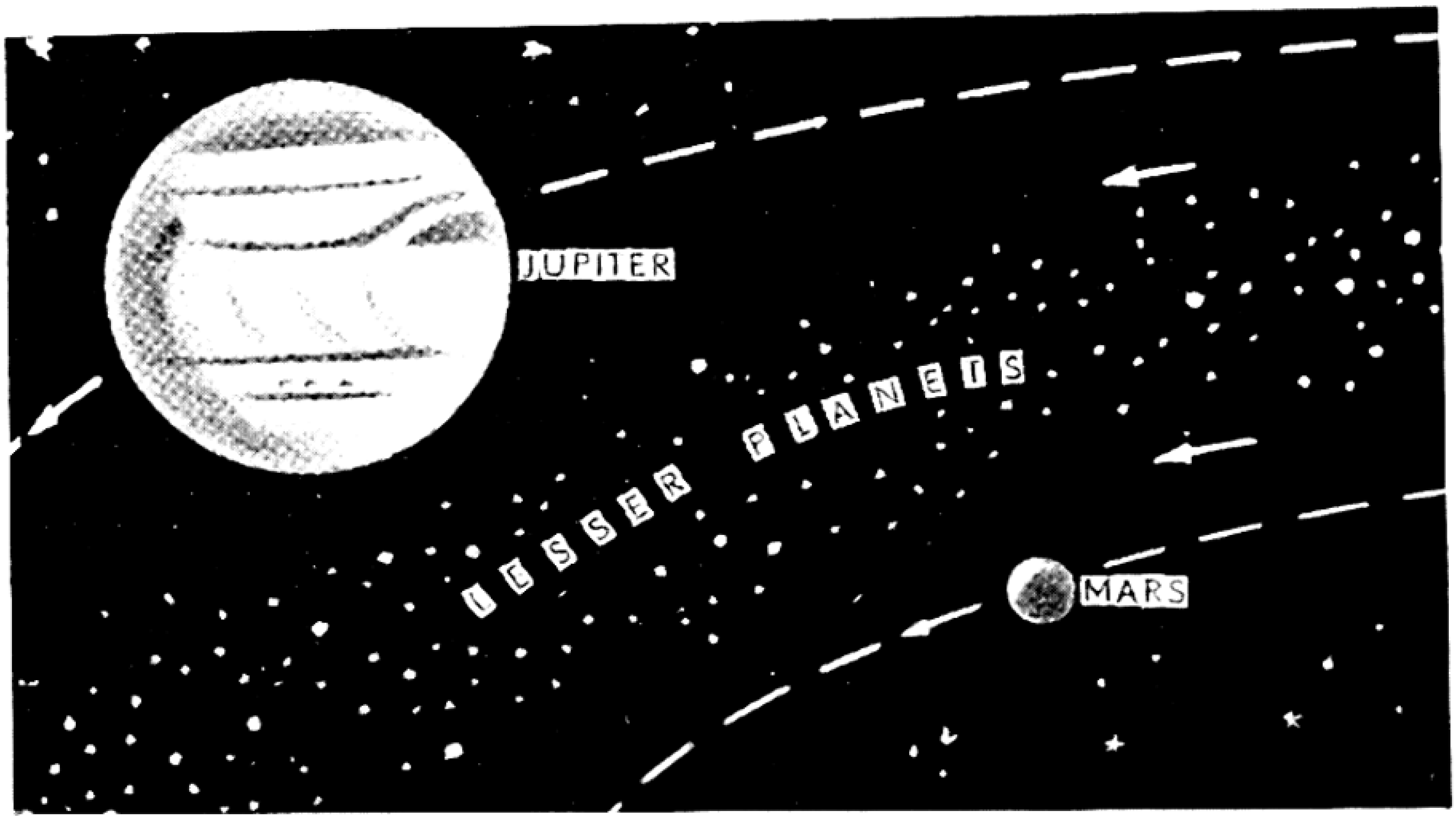
A year later another tiny planet, about the same size as Ceres, was discovered at approximately the same distance from the Sun. The astronomers were a bit worried about that: their calculations did not allow for a second planet. Since the planet was there it had to be given a name and was called after Pallas, the Greek goddess of wisdom.

Very soon the astronomers had even greater cause for disquiet; in 1804 a third planet, Juno, and in 1807 a fourth one, Vesta, were discovered.

These discoveries provided the astronomers with considerable food for thought. There were four very small planets where one big one had been expected and, like it or not, they had to be regarded as splinters or fragments of a bigger planet that had been destroyed. It seems that at some time there was a major catastrophe in space, somewhere between Mars and Jupiter, during which a big planet was broken up into a number of small pieces.

This was an idea that many nineteenth-century astronomers did not like. Here is what the famous German mathematician and astronomer, Karl Gauss, wrote to a friend: "Suppose we do learn in a few years from now that Pallas and Ceres were once a single body. Such a result from our studies would be undesirable from the standpoint of human interests. Imagine the unbearable horror that would overtake the people, what a struggle between piety and disbelief would begin, how some people would start to defend Providence and others to attack it! All this would be inevitable if it could be shown by facts that a planet can be destroyed. What would those people say whose theories are based on the unchanging stability of the solar system! What would they say when they found that their theories were built on sand and that a blind, accidental play of natural forces is everywhere supreme! Personally, I think we should refrain from drawing such conclusions. . . ."

Pallas, Juno and Vesta proved to be smaller than Ceres. They have the following diameters: Pallas, about 500 kilometres, Vesta, about 400 kilometres and Juno, a mere 200 kilometres. Of all these planets only Vesta is occasionally visible to the unaided eye: the others can be seen only through a telescope, when they appear as bright dots. For this reason they have been called asteroids, or star-like heavenly bodies. The planets appear as discs in the telescopes and only the stars are like bright dots.



The asteroid belt

Ceres and its neighbours are dwarf planets. Time, however, proved that they are giants compared with other members of that same family, and a very big family it turned out to be! A fifth member of the family was discovered thirteen years after the discovery of Vesta. It had been believed all those years that the four minor planets mentioned above were the only ones and then, in 1845, an amateur astronomer found a fifth which was named Astraea.

Very many amateur astronomers turned their telescopes, mostly home-made instruments, to the heavens. It was a very attractive idea—to look for a new planet in outer space! All the amateur needed was patience. He had to watch one section of the sky every night and mark the position of the stars accurately on a star map. If a star moved from its place relative to its neighbours, it was not a star but an asteroid!

Since it could not be predicted in which part of the sky the asteroids would appear the astronomer had to take a chance. Some of the amateurs were lucky enough to discover several new asteroids.

Year by year the number of newly-discovered asteroids grew until at last they could be counted in dozens. Very soon astronomers ran out of Greek and Roman goddesses and new planets were

called after Phoenician, Germanic and Norwegian goddesses. Then they were given simple women's names. A small group of asteroids which differed considerably from the others was given the names of gods—Hermes, Eros, Adonis. . . .

Many new asteroids have been discovered by Soviet astronomers and some of them have been given the following names: Vladilen, in honour of Vladimir Ilyich Lenin, Morozovia, in honour of the Russian revolutionary N. A. Morozov, Pavlovia, in honour of the famous Russian physiologist.

It has now become customary to designate newly-discovered asteroids by two letters following the year of discovery: 1937 T L (a minor planet discovered by the Soviet astronomer Neuimin).

Today more than 1,500 asteroids are known.

Although such a large number has been discovered, there are still more racing through space—scientists believe there must be tens of thousands of these tiny asteroids.

The first to be discovered were, of course, the biggest—you already know their names, Ceres, Pallas, Juno and Vesta. Later asteroids with diameters of 100, 50 and 20 kilometres were discovered. Today asteroids with a diameter of a kilometre and less are known. Compared with these dwarfs of the solar system Ceres and her sisters are real giants. Ceres has a circumference of about 2,500 kilometres, which would be quite a considerable distance to walk. Its area is about two million square kilometres, or one-sixth of Europe. France, Italy, Germany, Britain and about a dozen little countries such as Switzerland could all find a place on that tiny planet. But only about one-tenth of the Soviet Union would fit on to Ceres.

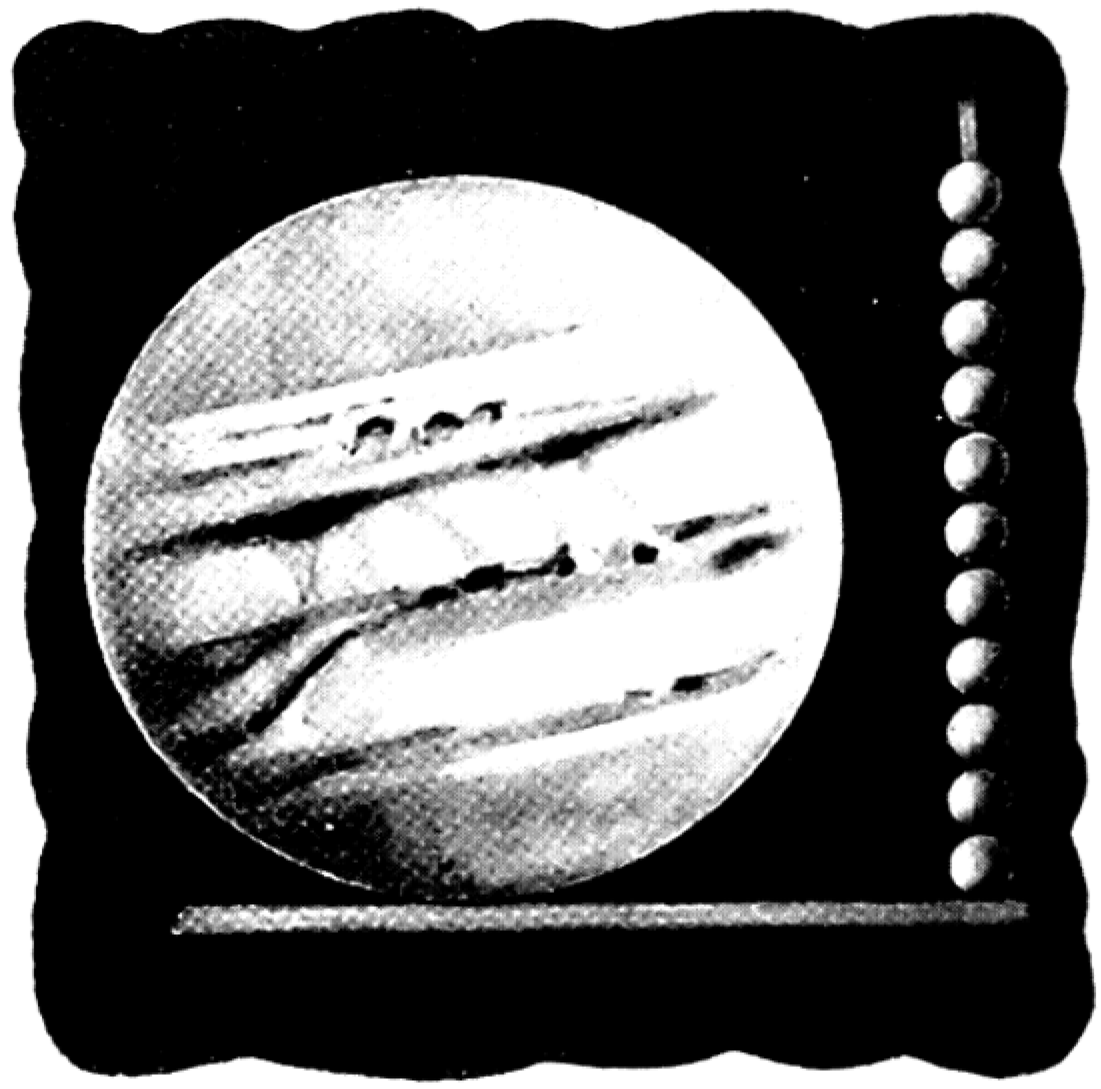
There are "pocket" asteroids about a kilometre in diameter that you could walk round in an hour; such bodies have a surface area of only 300 hectares. The volume of these pocket asteroids is 500 million times less than that of Ceres.

And so we see that the asteroid family has its giants and its dwarfs. Among the undiscovered asteroids there must be some with a diameter of a few dozen metres or even of a couple of metres. They are nothing more than big stones racing through space.

The presence of the big and little asteroids has led some astronomers to believe that at some time there really was a catastrophe in space and that a planet was blown to pieces. If so, it must have been quite a small planet, about a thousand times smaller than the Earth.

JUPITER

The group of giant outer planets begins with Jupiter. It is the biggest planet in the solar system so that there was good reason for giving it the name of the ruler of the Roman gods.



The comparative sizes of Jupiter and the Earth

Here are some figures that will give you an idea of how big Jupiter is.

Its diameter is eleven times that of the Earth. It would take a man on foot 800 days to walk round the Earth at the rate of 50 kilometres a day, but it would take him 25 years to make the same trip round Jupiter—at the same rate of 50 kilometres a day he would start out a youth and return in middle age.

The surface area on Jupiter is 120 times greater than that of the Earth.

At your geography lessons you have learned about the continents of the world—Europe, Asia, Africa, North and South America, Australia and Antarctica. Just imagine that there were continents of the same size on Jupiter: there would be room for 700 such continents on the surface of that huge planet. Geographers and travellers there would have plenty of work to do to study their native planet and whole libraries of books would have to be written to describe it. And what a time the schoolboys would have learning its geography!

One thousand three hundred globes the size of the Earth could be made out of Jupiter. The force of gravity, the force by which Jupiter pulls objects on its surface, is very great. If a man weighing 60 kilograms on Earth were to reach Jupiter he would weigh 140

The weight of an earthman on Jupiter (on a spring balance)

kilograms on that planet. The traveller to Jupiter would not jump about like we did on the Moon; his muscles would be too weak to drag his heavy body along; a man's own weight would press him down to the ground and he would scarcely be able to crawl. He would move about the surface so slowly that he would not be able to make one journey round Jupiter in a hundred years!

Some two or three hundred years ago many astronomers believed that there are people, reasoning beings, on all the planets. They argued this way:

"The Earth is a planet and it is inhabited by people. Mercury, Mars and Jupiter are also planets, so there must be people there, too."

The astronomers also believed that people of small stature lived on the smaller planets and giants on the bigger ones. Here they made a big mistake: if there were people on Jupiter they would be dwarfs for only very small people would have muscles strong enough to carry their small, light bodies on Jupiter. On the Moon the opposite is true: there is little gravity and giants could live there. But in the olden days scientists did not realize this.

There is no life on Jupiter.

The giant outer planets are differently built from the inner planets—Earth, Mars, Venus and Mercury. The smaller planets are composed of solid matter and have hard crusts of rocks. When space travellers fly on their rockets to any of the inner planets they will be able to land there. They would be threatened with destruction if they attempted to land on Jupiter.

The giant planet is surrounded by a very dense atmosphere consisting of gases that cannot be breathed. Jupiter's atmosphere is terribly cold; scientists have measured the temperature there and have found that it is —140° C. This is because Jupiter gets very lit-

tle heat and light from the Sun—the planet is five astronomic units away from the Sun.

Scientists still do not know what lies under Jupiter's dense atmosphere: some scholars believe that the central part of the planet is hot, while others think that the solid core is surrounded by a thick crust of ice.

Even if a spaceship did find a place to land under Jupiter's atmosphere the tremendous gravitation of the planet would not allow it to take off again.

Jupiter makes a complete revolution round the Sun once in twelve terrestrial years. This means that Jupiter's years are twelve times as long as ours but the days are very short—only ten hours long, five hours daylight and five hours night.

What would it be like on Earth if we had such short days? You would get up in the morning, eat your breakfast, go off to school, sit there during four lessons and ... it would be night again. How would you find time for play and to prepare your lessons?

Since there are no people on Jupiter, however, the length of the day does not matter.

Another way in which Jupiter differs from the inner planets is in the number of its satellites or moons: there are twelve of them, so that Jupiter and its satellites is a whole system in itself.

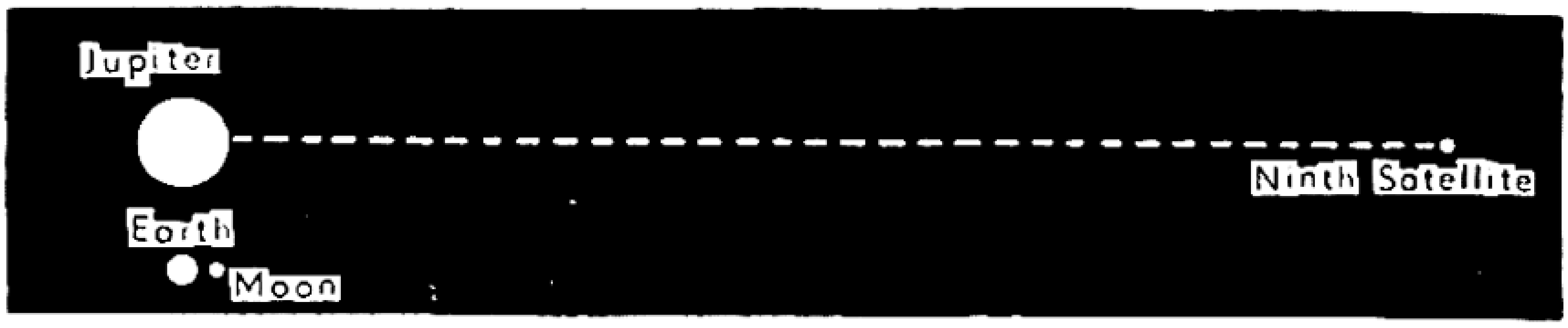
There are many interesting things to be learned about Jupiter's satellites.

You already know that the four moons nearest to the planet were discovered long ago by Galileo, the first man to study the sky through a telescope. His telescope was very weak but still he immediately noticed the four moons because they are quite big. Two of these Galilean Moons (that is the name they have today) are bigger than Mercury, one is bigger and the fourth somewhat smaller than our Moon.

For a long time after their discovery, Jupiter's satellites were of great value to mariners who sailed their ships by them across the oceans.

Since you will surely want to know how this could be done I will tell you how mariners in the olden days used Jupiter's satellites to find their way.

A ship is at sea, nothing but water for hundreds and thousands of kilometres all round; under the water there are rocks, shallows



This drawing shows Jupiter with its system of satellites compared with the Earth-Moon system
(Jupiter and the Earth are not drawn to scale.)

and islands that the ship might run into in fog or in the darkness of night.

Every day at noon the captain of the ship finds its exact position by the Sun and by using a very exact clock called a chronometer. Then he marks a spot on the chart to show where the ship is.

He can see immediately by his chart whether there are rocks or islands anywhere near the ship. But suppose the captain has made a mistake: he thinks there are rocks forty kilometres away and actually they are only ten kilometres from his ship. This could easily happen if the chronometer were wrong, if it were slow, for example.

In our days this is no problem because the captain checks his chronometer every day by radio. But a hundred or two hundred years ago there was no radio and clock mechanisms were not so perfect as they are today.

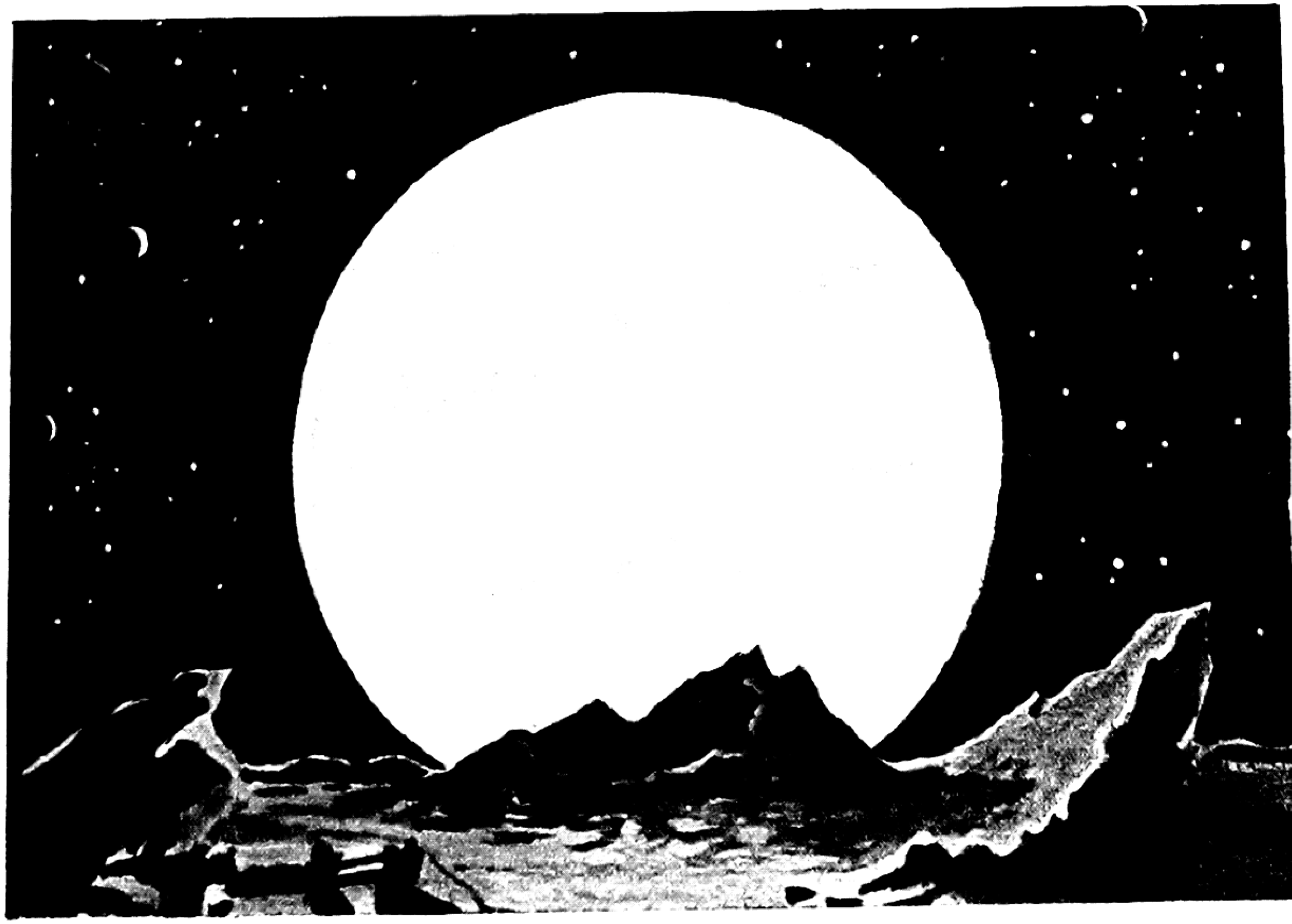
It was here that the Galilean Moons came to the captain's help. The Sun shining on Jupiter causes the planet to cast a huge shadow. When one of Jupiter's moons is in this shadow it is eclipsed. Over two hundred years ago astronomers already began to record the times of these eclipses and to predict them. Eclipse tables were published in special astronomic almanacs that every ship carried.

The captain looked at his almanac: today there will be an eclipse of Europe (one of the moons) so I shall be able to check my chronometer if there are no clouds.

When the time came the captain took his telescope and watched the sky. His first mate stood beside him with the chronometer in his hands.

"The eclipse is beginning!" said the captain.

"The chronometer shows 23 hours 14 minutes 37 seconds," said the mate and immediately wrote down the time.



Jupiter as seen from one of its satellites

"The almanac says 23 hours 15 minutes 16 seconds," said the captain, "our chronometer is 39 seconds slow."

Jupiter and its moons proved to be the most accurate heavenly clock that did not have to be wound up, that never had to be repaired or cleaned and was never a second fast or slow!

Even today the captains of ships, especially sailing ships, have astronomic almanacs—radio is a wonderful thing but suppose something goes wrong with it!

And so you see that astronomy, the science of the sky, is quite valuable on Earth. Many examples similar to this could be given.

The other eight moons are all very small and can be seen only through powerful telescopes; they are of little interest except to astronomers.

SATURN

Saturn is a gigantic planet whose volume is about 750 times that of the Earth.

Saturn was the most distant of the planets known to the ancients. Today we know of the existence of three more planets, all farther away than Saturn and visible only through a telescope.

The ancient Romans called the god of time and father of Jupiter by the name of Saturn; the planet is named after him.

Saturn is nine and a half astronomic units distant from the Sun. Its year is equal to almost thirty terrestrial years, so that a ninety-year-old terrestrial man would be only about three years old on Saturn!

There is no life on the planet. Like Jupiter it is surrounded by a dense envelope of gas, and its surface temperature is —150° C.

We could finish our story of Saturn with these details were it not for a wonderful feature that distinguishes it from all other planets.

Seventeenth-century astronomers with their weak telescopes were unable to solve the riddle of Saturn's queer appearance.

Saturn is the only planet in the solar system decorated with a ring, and the ring is of a very peculiar nature.

Take a piece of pasteboard or stiff paper and with a pair of compasses draw two circles from the same centre. Cut round the inner and outer circles with a pair of scissors and you will get a flat ring —this is a model of Saturn's ring.

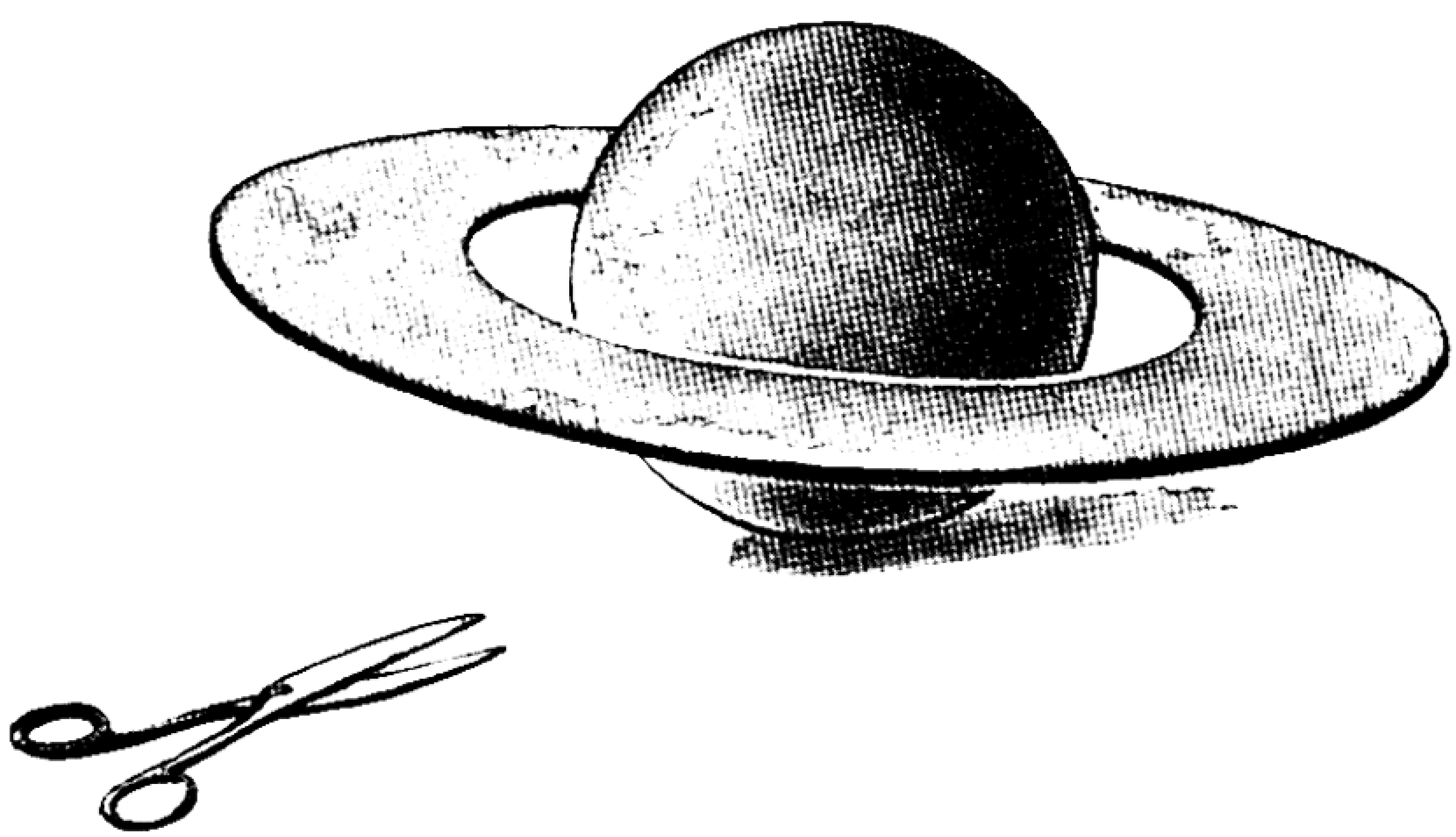
The ring does not lie directly on the planet but is at a distance of tens of thousands of kilometres from its surface.

Seen through a big telescope Saturn and its ring are a wonderful sight: against the background of a dark, velvety sky, Saturn looks like a marvellous toy, one of those whims of nature that she uses to show us what a great variety of heavenly bodies she is capable of creating.

Where did Saturn's ring come from? We are not yet quite sure about this. Astronomers believe that it is made up of fragments resulting from the destruction of Saturn's satellites.

The ring revolves around Saturn at a speed of 15 to 20 kilometres a second. It consists of tiny particles separated from each other and moving freely in space. These particles are of various sizes—from dust particles up to boulders weighing several dozen tons.

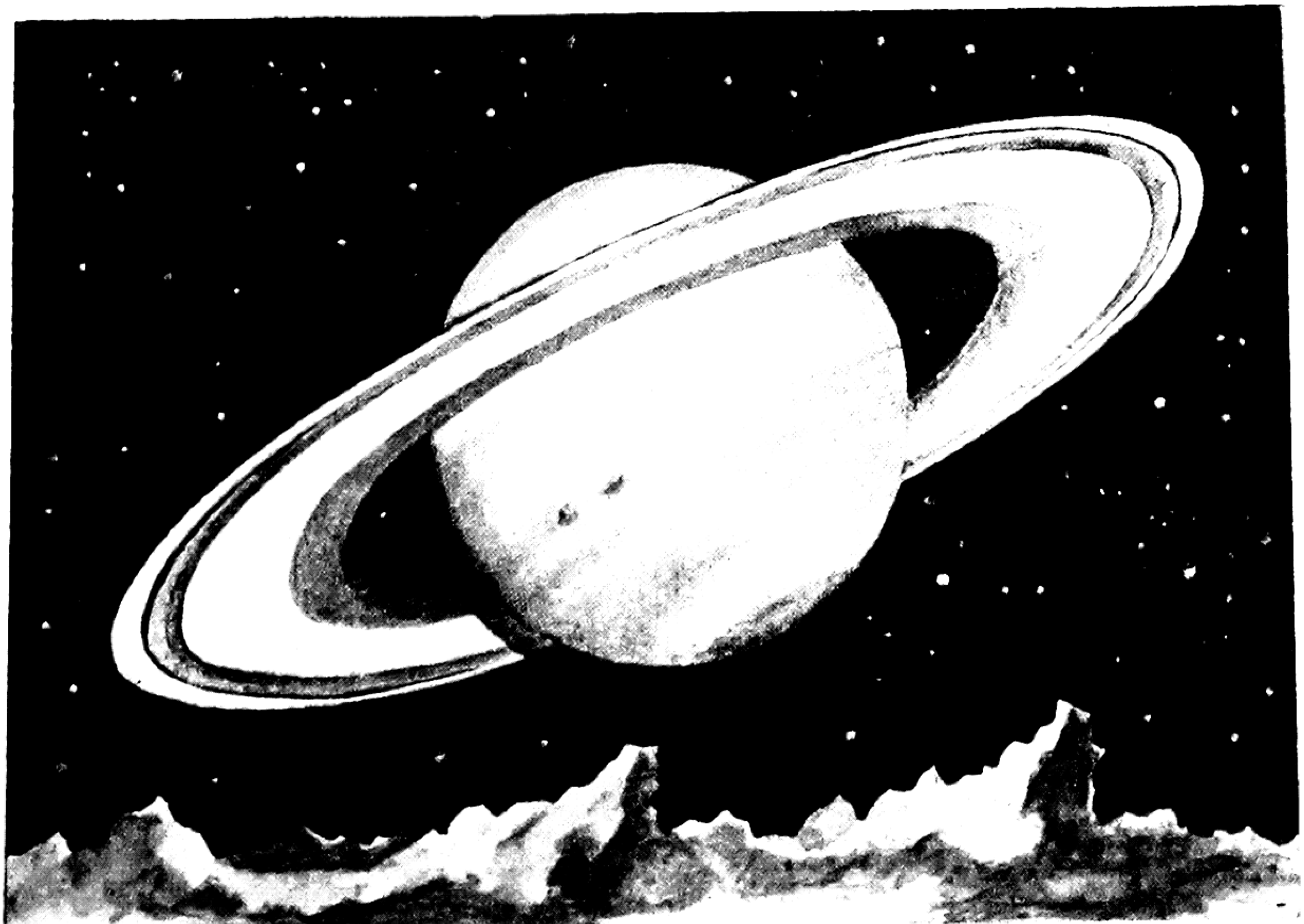
What makes us think that Saturn's ring is not solid? If Saturn's ring happens to be between the observer and some bright star the



star is quite clearly visible through the ring. This, incidentally, proves that the ring is quite thin, something like 15 kilometres....

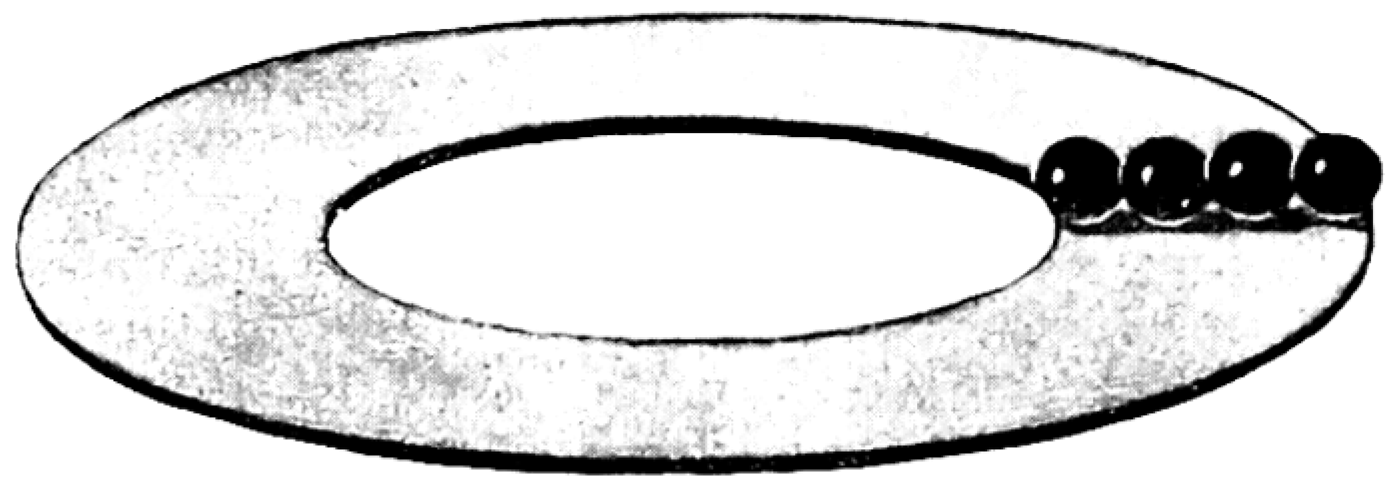
"You call that thin!" you say, smiling.

Yes, it really is thin in comparison with its tremendous width. You have the ring you cut out: select four marbles or beads small



Saturn as seen from one of its satellites

enough to lie side by side across the ring. Each of the marbles will represent our Earth on the same scale. That shows you how wide Saturn's ring is!



The number of Earths that can be placed on the width of Saturn's ring

From Saturn to the Earth the distance is about 1,500 million kilometres and when the edge of the ring is turned towards the Earth it cannot be seen in the most powerful telescope: it is like looking at a sheet of paper edgeways from a distance of a whole kilometre.

Once every fifteen years the ring disappears from the eyes of observers on Earth and at such times Saturn looks just like any other planet.

Here is an interesting story taken from the history of astronomy.

In 1921 Saturn was turned towards the Earth in such a way that the ring was invisible. The *Astronomical Almanac* recorded the disappearance of the ring.

The report was taken up by sensation-hunting newspapers in several countries.

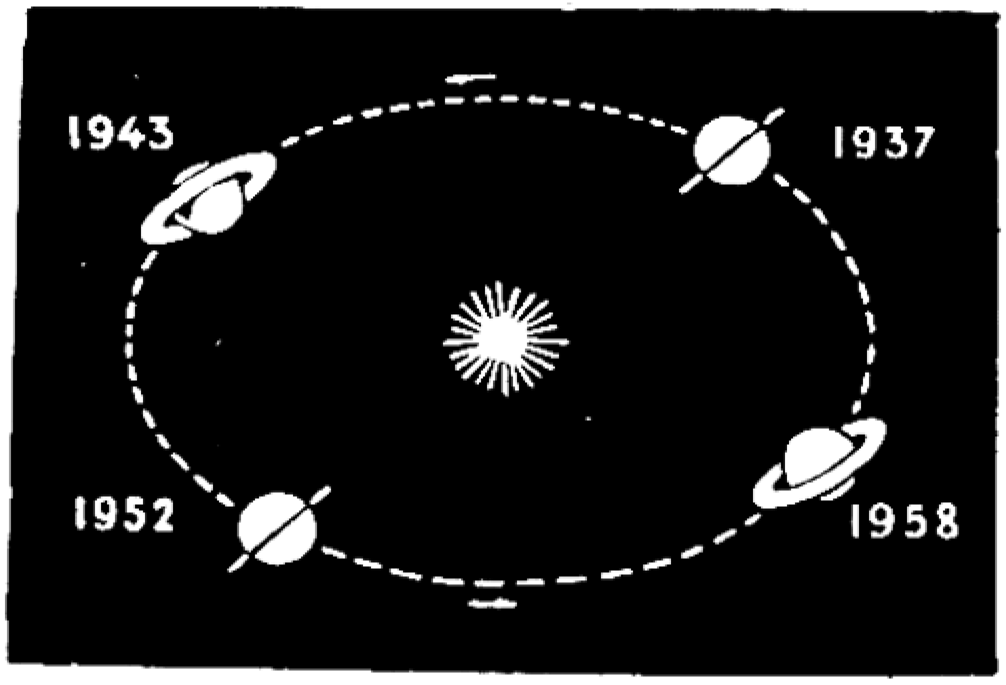
"Saturn's ring has disappeared!" screamed one newspaper. "It has burst into pieces!" (The ignoramuses believed it to be a solid ring.)

Another newspaper raised an alarm: "The fragments are flying towards us at tremendous speed! A cosmic catastrophe is inevitable!"

This caused a tremendous hullabaloo. The Church also raised its voice: "The end of the world is at hand! Repent, Christians, and pray!"

And this whole sensation was created by a tiny note written by an astronomer.

The ring, of course, soon reappears. At first it looks like a thin string and then it begins to grow wider and in seven or eight years



Saturn's ring as seen at different times from the Earth

"opens up" in full; it is best to observe it at this time. The years 1958 and 1959 were favourable for observations of Saturn's ring and it was seen by observers on Earth in all its beauty.

If the boys and girls who are reading this book have a good telescope available or are able to visit an observatory, they should take the opportunity of seeing one of the most amazing heavenly phenomena—the view of Saturn with its ring.

Apart from the ring, Saturn has nine satellites, the biggest of which is twice the size of our Moon.

URANUS

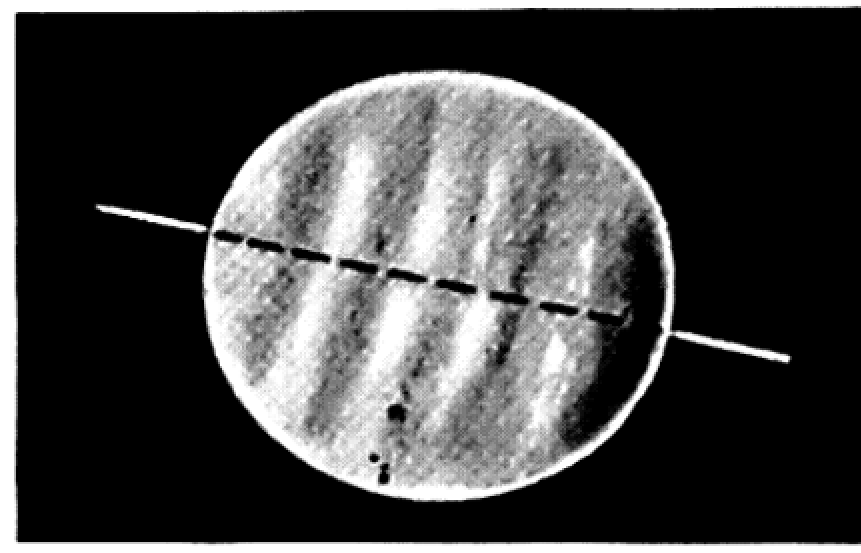
Uranus is a very long way from the Sun, nineteen times farther than the Earth. Light from that planet is very weak and it was accidentally discovered through a telescope in 1781. I have already told you that the ancient Romans believed Saturn to be the father of Jupiter, and Uranus, the god of the sky, was the father of Saturn. For this reason the planet that was discovered farther from the Sun than Saturn was given the name of Uranus.

The year on Uranus is as long as eighty-four earthly years: not many of our earthlings could hope to live two Uranus years. The day on Uranus is only 11 hours long so that there are over 72,000 days in a year!

Uranus has a peculiarity that distinguishes it from all the other planets in the solar system. All the other planets revolve around the Sun so that their axes are vertical or slightly deflected from the vertical. But Uranus is like a top that spins lying on its side.

On account of this peculiarity Uranus experiences a very strange change of day and night. Sometimes the end of the axis, the pole,

is pointed directly at the sun. At these times an observer standing at the Uranian pole would have the Sun directly overhead.



Uranus

What is the effect of this? The Sun's rays light up the pole and the arctic regions most strongly, and farther, towards the equator, the sunlight slants down at a lower and lower angle, until at the equator itself, the Sun is just over the horizon. Everything on Uranus, therefore, is exactly the opposite of what it is on Earth. The hemisphere opposite the Sun enjoys daytime, and the daylight lasts many terrestrial years and thousands of Uranian days. At the pole itself the daylight lasts for 36,000 Uranian days and nights.

You see from this how inexhaustible nature's inventiveness is.

Uranus has five satellites and even the biggest of them is much smaller than our Moon.

NEPTUNE

Counting outwards from the Sun, Neptune is the eighth planet and is the last of the group of big planets.

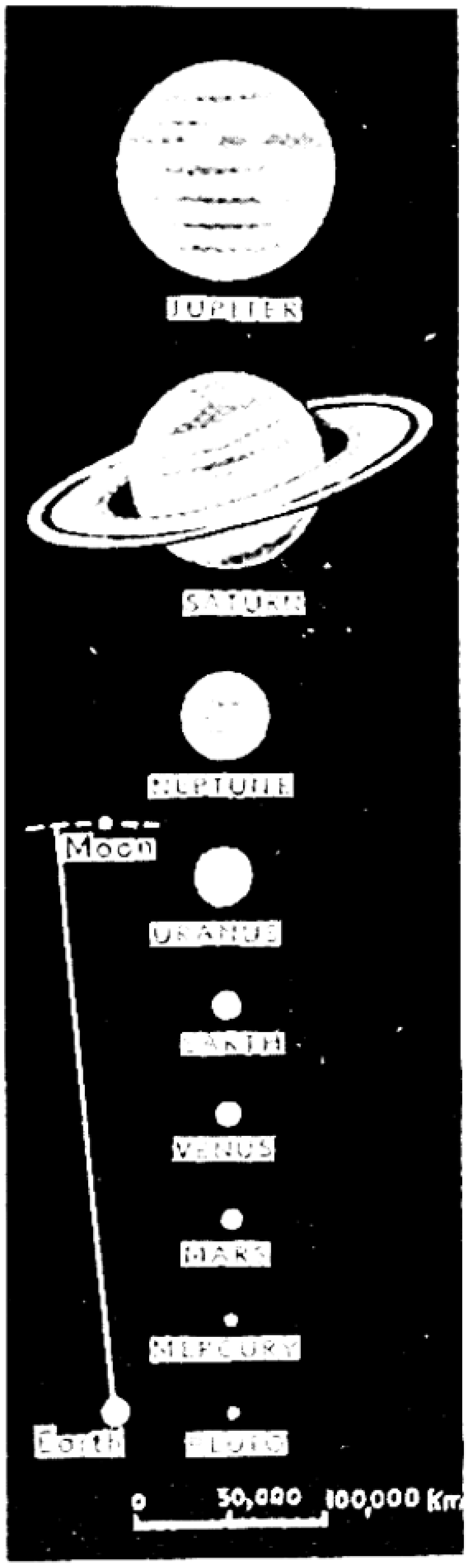
The history of Neptune's discovery is worth relating.

It was not discovered by an astronomer studying the sky through a telescope but by a mathematician who sat in his study, pen in hand; while making his calculations he did not even look once at the sky.

I will tell you something about this great event in the history of astronomy.

You already know that Uranus revolves round the Sun once in 84 years. Its apparent motion in the sky is very slow although it moves at a rate of about 7 kilometres a second. I must remind you again that the velocity of a shell as it leaves the muzzle of a gun is only two kilometres a second.

But Uranus is a long way away from us, so that its motion among the stars in the sky seems exceedingly slow. Astronomers calculat-



The relative sizes of the planets: the Earth and the Moon are shown separately and the distance between them is drawn to the same scale as the diameters of the planets

ed the movements of Uranus for many years ahead. They calculated exactly where Uranus should be in twenty, forty and sixty years after its discovery.

And what happened? Forty years later the planet was not where it should have been and after another twenty years it was still farther from the estimated place. You might think the deviations too small to worry about. Stand a match up on end and then walk seven steps away from it. Does the match seem very thick (or wide) to you at that distance? That is just the distance by which Uranus' real position differed from that which had been calculated dozens of years before. All this may seem very trivial to you. But the astronomers decided that it was far from trivial, that there must be some reason for Uranus moving out of a regular path. They began to seek the cause.

You already know that the force of gravity operates at any distance but that the greater the distance the weaker the force. We say, for example:

"The Earth revolves around the Sun because the Sun attracts it."

That is true. But to this we must add that the Earth is attracted not only by the Sun but also by the Moon, and Mercury, and Venus, and Mars, and Jupiter, and all the other planets. Even the distant stars attract the Earth but they are so far away that the force of their gravitation is not worth considering. The force of gravity exerted by the planets, however, must be considered.

Here is an example. When the Sun and Jupiter are on the same side of the Earth the force of gravity is increased—Jupiter helps the Sun attract the Earth. But when the Sun

is on one side of the Earth and Jupiter on the other the reverse is the case: the Sun pulls the Earth to itself and Jupiter pulls the other way so that the Sun's attraction is slightly weakened. In the first case the Earth approaches slightly nearer the Sun than it would if it kept to its regular orbit; in the second case the Earth deviates slightly in the direction of Jupiter.

These deviations caused by Jupiter's attraction of the Earth are called perturbations or disturbances. It stands to reason that when an astronomer calculates the Earth's path through space he must consider not only the perturbations caused by the gravitation of Jupiter but also those caused by the Moon, Venus, Mars and the other planets. This is a tremendous job.

This great work was done by astronomers to calculate the path of Uranus. They took into consideration the perturbations caused by all the known planets. Nevertheless, as we have seen, the path of Uranus was not calculated correctly.

Perhaps the astronomers were wrong in their calculations? This, however, was not the case. Astronomers calculate with very great accuracy. If you want to become an astronomer you will have to get a mark of "excellent" in mathematics all the time you are at school.

And so, if the calculations were correct and Uranus did not move as predicted, it meant there must be another planet, still unknown, that attracted Uranus.

By calculating the perturbations that were caused by the unknown planet its position in outer space had to be found.

It would probably be easier to find a ball-bearing lost in a field of tall grass by watching the action of a compass needle placed in the middle of the field. The task of finding the new planet was one of extreme difficulty and required many months' work at the most intricate calculations. Nevertheless, it was done.

Leverrier, a young French astronomer, completed the calculations and wrote to the observatory: "Look for the new planet near the constellation of Capricorn."

The planet was found the very evening the letter was received. It appeared in the telescope as a small circle of light and not a point, like a star.

All this happened in 1846.

The new planet was called Neptune, after the god of the sea.

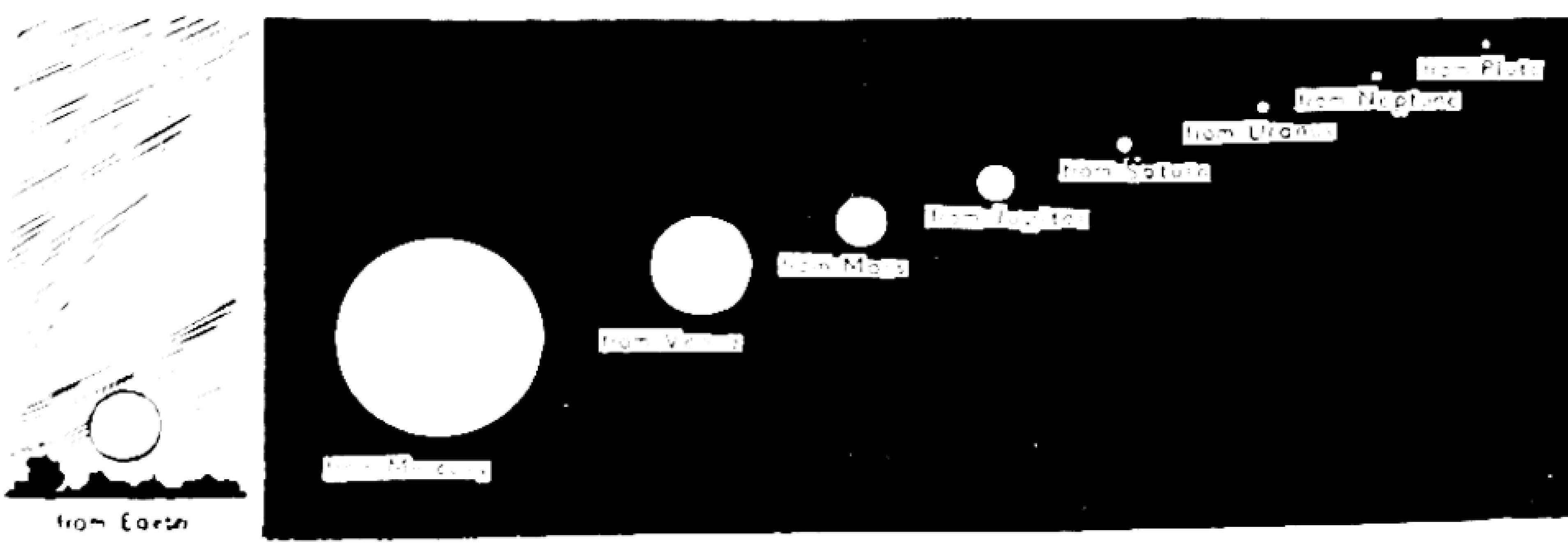
In size Uranus and Neptune are twins like the Earth and Venus. Each of them is about sixty times the size of the Earth.

Neptune is 30 astronomic units from the Sun and its year is as long as 165 terrestrial years. More than 100 years have passed since Neptune was discovered and in all that century Neptune has not made one complete revolution around the Sun.

Neptune has two satellites: one of them is the equal of Mercury in size: the other is quite small and was only discovered quite recently, in 1949.

PLUTO

Pluto was the Roman god of the underworld. He lived in eternal darkness that was broken only by flashes of hell-fire where the sinners were burning.



The Sun as seen from the different planets

Astronomers gave the name of Pluto to the most distant of all the planets yet known to man.

Pluto is forty times farther away from the Sun than our planet Earth and its year is about 250 terrestrial years.

Every square metre of Pluto's surface gets about 1,600 times less light and heat from the Sun than is the case on Earth. Seen from

Pluto the Sun must be a tiny disc that has a diameter about 40 times less than the Sun as we see it.

It cannot be said, however, that eternal darkness reigns on Pluto. On the sunny side of the planet the Sun gives 275 times more light than our full Moon. To make our night as bright as Pluto's day we should have to place 275 full moons in the sky. And so you see, how much light our Sun gives and how well it lights up the huge space around it.

Even so, the Sun's rays are too weak to give any warmth to Pluto and the temperature there is about —200° C.

Pluto was discovered quite recently, in 1930. In the time that has elapsed since then Pluto has made only a small part of its revolution round the Sun, less than an eighth.

The planet is so far away that even in a powerful telescope it looks like a tiny point of light and does not appear as a disc. Astronomers have not yet had time enough to examine Pluto in detail. It is not yet known whether it rotates around its axis, whether it has an atmosphere and satellites.

Pluto is a small planet; it is believed to be about the size of the Earth.

Are there any more planets farther away than Pluto? It is possible that there are but it will be very difficult to find them, the distance is too great.

METEORS

Long, long ago people believed that the stars were lanterns hanging from a crystal sphere. They believed that every man had his star that would go out on the day of his death.

When a bright star flew across the sky and then went out, pious people crossed themselves and said:

"Somebody's soul has returned to God. . . ."

People called the bright points of light that fly across the sky "shooting stars." They did not know in the olden days that every star is a distant sun that is millions and even thousands of millions of times bigger than the Earth.

Meteors are sometimes very bright. They fly across the sky like balls of fire rather than stars. It sometimes happens that the fiery ball is brighter than the Sun. Big meteors of this kind are called bolides.

What are these bodies and why are they called meteors?

Streams of stones and dust are constantly flying through space: some of these are the remains of heavenly bodies that have been destroyed. They cannot be seen through a telescope because they are too small. If, however, stones or dust particles from these streams enter the Earth's atmosphere they immediately get red hot on account of the friction caused by their flight through the air and they blaze up like bright stars.

Astronomers are interested in meteors. Of course, they do not study single meteors but whole streams of them. Flashes made by meteors in the upper layers of the atmosphere help determine the height of the Earth's atmosphere.

Meteors seldom fall on the Earth, they usually burn up completely in the atmosphere. If the stones are very big they may reach the surface of the Earth in one piece of after they have burst into fragments. A meteor or its pieces that reach the Earth are called meteorites.

On the morning of June 30, 1908, in the Tungus Taiga, about a thousand kilometres north of Irkutsk, in Siberia, a colossal meteorite fell to Earth. It was so bright at the time of its fall that it made the sunlight seem pale.

When the meteorite struck the Earth there was an explosion of terrific force; it shook the Earth to such an extent that reverberations were felt in Central Europe. The air wave caused by the blast travelled twice round the Earth.

Over an area of several thousand square kilometres giant trees were felled by the blast like leaves of grass. They all lay with their tops pointing away from the centre, that is, from the place where the meteorite struck the Earth.

It is interesting to note that the night after the Tungus Meteorite fell was very bright all over the Earth, as though the globe were enveloped in a cloud of light.

The tsarist government did not bother to investigate the meteorite. It was only in Soviet times that the Soviet Academy of Sciences equipped an expedition to the Tungus Taiga. It was headed by L. A. Kulik, a bold explorer. He found big holes in the ground at the place where the meteorite fell and they were full of liquid mud. He did not find any fragments of the meteorite.

Another huge meteorite struck Siberia in Soviet times; it fell in the Sihote-Alin Mountains, in the Far East, on February 12, 1947.

The Sihote-Alin meteorite appeared in the sky at 10.36 a.m. near the town of Iman in the form of a ball of fire with a smoke tail of many colours. The bolide shone more brightly than the Sun and burst with a terrific noise.

The craters it made on the snow-covered slopes of Sihote-Alin were seen from aircraft flying overhead. An Academy of Sciences expedition set out for the site immediately.

Since the scientists were "hot on the trail" of the meteorite they were able to collect several thousand fragments the total weight of which was about 40 tons; the biggest piece weighed 1,745 kilograms. Scientists, however, computed the total weight of the meteorite at about 1,000 tons.

The majority of the fragments either went deep into the Earth or were broken into pieces too small to find.

If you go out into the open on a fine evening and stand for an hour or two watching the sky you will probably see the bright star of a meteor flash up and die out again. You may see several of them from one place; just imagine how many of them fall all over the world in the course of twenty-four hours! Meteors are falling day and night but in the daytime you can only see the big ones, the bolides.

In the course of a year thousands of millions of meteors collide with the Earth. Of these only a few thousands reach the surface of the Earth in the form of meteorites. Only a few, five, perhaps ten, fall into the hands of astronomers. In the museums of the whole world there are about 1,200 meteorites and in the Soviet Union, at the time the Sihote-Alin meteorite fell, there were only a hundred odd.

The investigation of the substances from which meteorites consist is of great importance to science. The meteorite comes flying to us out of the depths of the solar system, perhaps, even, from some more distant star. The opportunity to take a piece of "heavenly" matter into his hands is a very attractive one for the astronomer. For this reason meteorites are considered state property in the U.S.S.R.

A meteorite of "Pallas iron"

It is usually very difficult to find a meteorite that has fallen to Earth. When it falls one gets the illusion that it has fallen in a near-by forest, or in a neighbouring village. Actually it has fallen a long way away from the place where the observer is standing.

Many meteorites fall in inaccessible places: in deserts, in the taiga or in rivers or seas. This explains why every meteorite found is a real treasure for science—it has greater value than a nugget of gold the same size.

And if you, my young friends who are reading this book, understand how important it is to search for fallen meteorites, the science of the sky will obtain much more material for research than it has formerly been able to obtain.

Now let us go back a thousand years in history.

The chronicler wrote in his record: "An enormous fiery dragon fell from the sky, hissing and roaring. . . ."

What was that dragon?

For many centuries legends have been handed down about fire-breathing dragons with long, fiery tails. These legendary dragons flew through the air on wings of fire and brave knights and warriors fought them.

But who, indeed, actually saw a fiery dragon? Were they invented long ago by old people, sitting by a warm fire, who told tales to the children to while away the long winter nights?

Although they were inventions, all these legends and folk-tales were founded on fact.

The fiery dragon was, of course, a bolide such as are often seen flying across the sky; the bolide itself was the head and fiery jaws of the dragon and the trail of fire or smoke it left behind it was the dragon's tail.

The appearance of a fiery dragon in the sky was regarded as a

sign or portent; it frightened the people and was even recorded in the chronicles of the day.

But the centuries passed and science developed. Scholars still knew nothing about meteors and there were even those who did not believe that stones could fall from the sky and regarded such stories as the idle chatter of people with nothing better to think about.

The Russian academician Pallas was the first to begin making a proper study of meteorite stones. In 1772 he reported to the Academy of Sciences at St. Petersburg that a block of iron mixed with nickel had fallen from the sky in Siberia; it weighed about 640 kilograms. The lump of iron was taken to St. Petersburg; this was the first exhibit in the now famous Academy of Sciences meteorite collection. Pieces of "Pallas iron" were sent to the academies of many countries to be studied, and it was only after this that scientists admitted that the meteorites really did fall from the "sky."

And so you see that "heavenly" matter has been studied for less than two hundred years.

You may wonder whether the bolides were found to contain substances that do not exist on Earth. No metals or minerals have been found in them that we do not already know; mostly they consist of iron, nickel, aluminium, oxygen and sulphur.

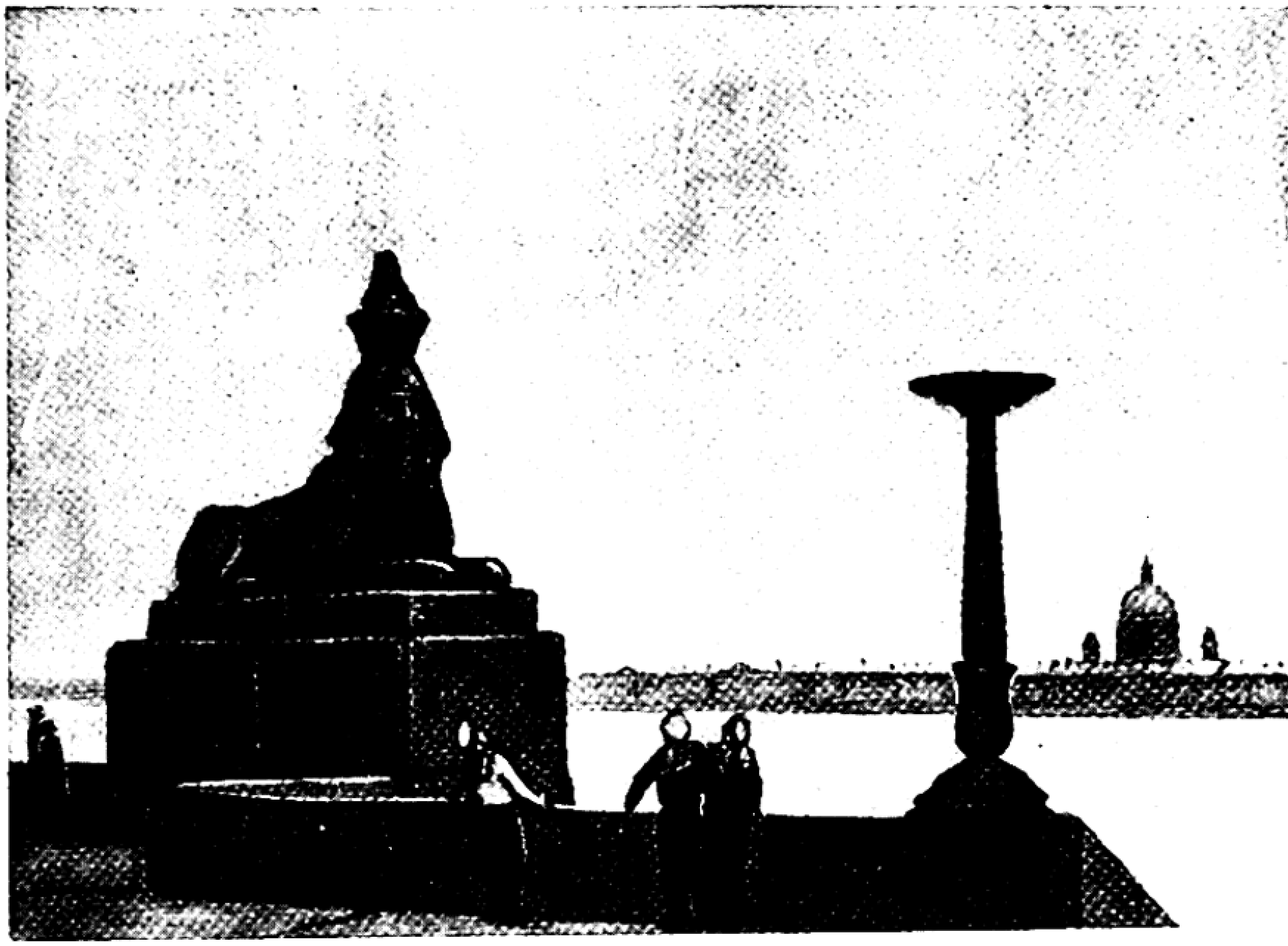
There are meteorites that consist of almost pure iron. Some historians even think that the first iron implements were made by man from meteorite iron and that it was only later that man learned to smelt iron from the ore.

All solid bodies in the Universe consist of the same substances, but it is important to know the form in which they reach us from different parts of the Universe.

STAR SHOWERS

There are nights when thousands of meteors flash up. The whole sky is lined with their bright trails and it seems to the observer on Earth that showers of stars are falling from the sky.

When do these star showers occur? They occur on nights when the Earth is passing through a meteor stream consisting of count-



A star shower

less tiny stones and dust particles. These stones and dust particles enter the Earth's atmosphere in hundreds and thousands and immediately burn up.

How great is the mass of the meteorites that fall on to the surface of the Earth each year? We have already said that there are thousands of millions of them; those that burn up also reach the surface of the Earth as tiny dust particles and the gases produced by combustion also have weight. In this way every meteorite that reaches the Earth, no matter how small it may be, increases the Earth's mass.

You may conclude from this that the mass of the meteorites that fall to the Earth each year is very great, but this is not so; altogether they weigh only a few thousand tons and if they were collected they could be carried on two goods trains.

The majority of the meteorites are nothing but tiny dust particles and the big ones, the bolides, are very rare. The mass of the Earth certainly does increase each year but only by a very slight amount.

The Earth is protected against the bombardment of meteors by its atmosphere. In general, the atmosphere is of the greatest benefit to us. We not only breathe its air—life without air to breathe would be impossible—but it is also a reliable shield that protects us from all kinds of meteorites, large and small, that menace the Earth every second of its existence. These bodies are like shells fired at us but not more than one thousand-millionth part of them ever reaches the surface of the Earth.

Why are there so many craters on the Moon?

Some scientists have suggested that these craters have been formed by big meteorites bombarding the Moon for millions of years. There is nothing to check this bombardment because the density of the Moon's atmosphere is insignificant. It is true, of course, that there are other astronomers who believe that the craters were formed by volcanic activity in the Moon's crust.

HAIRY STARS—THE PORTENTS OF MISFORTUNE

The word comet comes from the Greek word *kometes*, meaning long-haired. The Greeks gave this name to the comets because of the magnificent tails that can be seen when they approach close to the Sun.

In ancient days the comets, like the solar eclipses, caused great fright. There was no end to the horrors that were blamed on these innocent luminaries.

"Comets spread cholera, plague and other infectious diseases."

"Comets bring warning of wars, famine, floods, drought, earthquakes—in a word, all possible calamities. . . ."

"Comets bring death to kings, emperors and popes. . . ."

When people gazed at the comet, its fiery tail seemed to them to be a flaming sword or dagger, or a celestial broom that would sweep sinners off the face of the Earth. The drawing on page 152 shows you the horrors people saw in the comet of 1528.

This drawing is taken from an old book by Ambroise Paré, *Celestial Monsters*. It depicts the comet of 1528. The caption under the drawing said: "This comet was so terrible and caused such terror among the people that many of them died from sheer fright, others were stricken by sickness. It was unusually long and the colour of blood. On it was depicted a bent arm holding a gigantic sword as though to cut somebody down. At its point three stars shone brightly. On both sides of the rays emanating from the comet there were numerous bloody axes, knives and swords, among which could be seen the heads of decapitated people with the hair on them tousled"

The appearance of every comet was recorded in the chronicles with a description of the calamity it foretold. Here is the way a comet is described in a Russian chronicle for the year 1066: "At this time there was a portent in the west, an enormous star whose rays seemed to be stained with blood, it rose in the evening after sunset and remained for seven days; then came internecine wars and the invasion of the Russian land by the Polovtsi; a bloody star always portends bloodshed. . . ."

In 1378, two years before the famous battle of Kulikovo, when the power of the Tatars was broken, the chronicler wrote: "There was a strange occurrence, and for many nights there was this portent in the sky; in the east, before dawn, a star with a tail in the shape of a spear appeared many times. . . . This appearance foretold the evil invasion of the Russian land by Tokhtamysh and the brutal attacks of the pagan Tatars on Christian people. . . ."

Even many centuries later, in 1811, when a bright comet was seen in Russia, the people believed that it foretold war. And it so happened that a year later Napoleon's army attacked Russia. The Patriotic war of 1812 began, Moscow was burned to the ground. . . . Popular faith in the evil properties of the comets was only strengthened by this.

EDMUND HALLEY AND HIS COMET

The comets were real bugbears for the ordinary people. But how did the scholars regard them? In ancient days scientists thought that comets were atmospheric phenomena similar to the Northern Lights, storm clouds and lightning. Many scientists believed that comets are clouds of some harmful gases burning in the air.

The first astronomer to investigate comets was Tycho Brahe who lived at the end of the 16th century. In 1577 he succeeded in measuring the distance to a comet and found that it was very far from the Earth, much farther than the Moon. The Moon, he knew, was a heavenly body and so the comet must also be a heavenly body.

Tycho Brahe died in 1601. After him the study of comets was taken up by another famous astronomer, Kepler. Since comets frequently pass close to the Earth and space is boundless, Kepler came to the conclusion that there are as many comets in space as there are fish in the sea. He was, however, mistaken in believing that the comets travelled along a straight line.

"The comets appear out of space," said Kepler, "pass through the solar system and then disappear for ever."

This is an entirely wrong view for there are no heavenly bodies that move in straight lines; the comets mostly move in elongated circles or elipses and disappear only to appear again.

The English mariner and astronomer, Edmund Halley, was the first to discover that the comets are regular inhabitants of the solar system. Halley studied old records of the appearance of comets and noticed that the periods between the appearances of some of them were practically equal. There were, for example, comets in 1531, in 1607 and 1682.

Scholars thought that these were all different comets. Their paths through the sky, however, were all very similar. The comet of 1682, incidentally, Halley observed himself and recorded its path across the sky, its orbit. Halley reasoned in this way: from 1531 to 1607 is seventy-six years and from 1607 to 1682 is seventy-five years. Events occurring at regular intervals are called periodical. Suppose the appearances of the comets were periodical, even if not exactly? If this were true it would mean that the comets revolve round the Sun in a very elongated orbit and that one revolution would take seventy-five and a half years.

The irregularity in the motions of the comet were easily explained: in its orbit the comet passed close to Jupiter and Saturn and these enormous planets had sufficient force of gravity to cause disturbances of its motion.

"If my judgement is correct," said Halley, "the comet should appear again in 1758." Halley published his investigations and astronomers of other countries learned about them.

Edmund Halley lived a long and useful life which he devoted to scientific investigation. He died at the age of 86 in 1742, sixteen years before the appearance of the comet he had forecast. And the comet appeared at the appointed time.

In this way Halley proved the periodicity of comets and it was then obvious that they are members of the solar system.

The comet was called Halley's Comet in his honour and bears that name to this day.

Comets are not usually given names of their own, like the planets. If a comet is periodical it is called by the name of the astronomer who discovered it or who determined its path. If its periodicity is not proved it is called after the year in which it appeared close to the Earth—the comet of 1811, for example.

THE PATHS OF THE COMETS

Astronomers have experienced considerable difficulty in studying the paths, or orbits, of the comets in space. Since comets were first recorded about fifteen hundred of them have appeared. It is true, also, that not every comet was recorded in the ancient chronicles and, what is still more important, many written records have been lost in wars and fires.

In the majority of cases the orbits of the comets are extremely elongated. We now know many comets whose period of revolution about the Sun is not very great, but others have been discovered in outer space that have a year that is much longer than those of Uranus, Neptune or Pluto.

The bright comet of 1858 recedes from the Sun to a distance of 150 astronomic units, that is, 22,500 million kilometres, four times farther from the Sun than Pluto is. At that distance the Sun would

appear as a tiny star but it would still be about twenty times brighter than the Moon.

At such a distance from the Sun the comet moves little faster than a pedestrian. The nearer the Sun, however, the greater is the effect of the Sun's gravitation and the greater the velocity of the comet.

In the vicinity of the Sun many comets move at a velocity of 400 to 500 kilometres a second. It is only this tremendous velocity that prevents them from being drawn into the Sun—the centrifugal force due to velocity counteracts solar gravitation.

Astronomers have computed that one revolution of the 1858 comet about the Sun takes two thousand years. It will next pass close to the Earth in the 39th century. It will appear if nothing happens to it on its journey. It may collide with an asteroid and both of them may break up, or it may pass too close to Jupiter or Saturn and the gravity of the planet may change its orbit.

A bright comet

The 1858 comet is not the most remarkable of the comet family. Comets that make one revolution in ten thousand years have been discovered. They travel inestimable distances into outer space but they inevitably return, so great is the attractive power of the Sun.

THE STRUCTURE OF A COMET

The comet is usually described as consisting of three parts: the nucleus or core, the head and the tail.

Specialists in comet study watch the sky every night in case a new comet should appear. Whenever a hazy round patch appears within the telescope's field of vision that was not there before, they immediately say: "That is a comet!"

A comet does not possess the clear outlines of a planet, its edges are hazy and indistinct. This is because the centre of the comet, the stone nucleus, is surrounded by an envelope of gas. This outer envelope of gas is called the head of the comet.

Some of the comets have heads of tremendous size: Halley's Comet, which last appeared in 1910 (the author of this book was lucky enough to see it), had a head 370,000 kilometres in diameter, more than double the diameter of the gigantic planet Saturn. There are even comets with a diameter greater than that of the Sun.

Halley's Comet

These must be the giants of the solar system, you may think. But they are not, because the head of a comet consists of extremely rarefied gases. The "vacuum" of an electric lamp, from which the air has been extracted so that the filament will not burn up, is a thousand times denser than the gas surrounding the comet nucleus.

The stone nucleus of the comet is no bigger than an asteroid, and not a big asteroid at that.

Neither the nucleus nor the head of the comet, however, is its most important part—the important thing about a comet is its tail. It is this tail, this astounding fiery spectacle, that has put fear into many people from time immemorial.

The problem of what the comet's tail consists of is a very difficult one.

Lomonosov pondered for a long time over the question: why is the comet's tail always pointing away from the Sun. He believed that some force of repulsion emanated from the Sun which drove the particles of the comet outwards. This wonderful guess was proved to be true more than a hundred years later.

Fyodor Bredikhin (1831-1904)

In the latter half of the 19th century, Professor Fyodor Bredikhin of Moscow University (1831-1904) made a study of comet tails. This is what Bredikhin and later astronomers tell about the tail of a comet.

A huge block of stone or, perhaps, a mass of smaller stones, is racing through space far from the Sun. The space between the tiny particles of the stones is filled with gases such as nitrogen, carbon dioxide, cyanogen (a very poisonous gas).

As the comet nears the Sun the stone is heated by the Sun's rays, the gases inside it expand and exude from the stone. These gases form the head of the comet.

When the comet approaches to within a distance from the Sun, that is about equal to the Earth's distance from that body, the repulsive action of the Sun drives the gases out of the head and the tail is formed. The tail grows as the comet nears the Sun and is all the time turned away from that luminary. The length of a comet's tail is measured in millions and hundreds of millions of kilometres. There was one comet with a tail 900 million kilometres long.

It has been discovered that there are two forces that repel the gases: the nature of one of them is still unknown and the other is light pressure.

The Russian physicist Pyotr Lebedev showed that light exerts pressure on all the objects on which it falls.

The power of light pressure is insignificant: the pressure on the whole of that part of the Earth's surface which faces the Sun is only about 10,000 tons. Light pressure would not repel a pea or a grain of wheat because their mass is too great compared with their surface area. Tiny particles, however, have an infinitesimal mass and light pressure is enough to set them in motion. This discovery was of great importance to science, for many phenomena connected with the comet's tail are explained by light pressure.

As the comet draws away from the Sun its huge tail is dispersed in space and the comet again becomes merely a block of stone invisible through a telescope.

THE FATE OF A COMET

Can the comet nucleus expel gas for a long time?

Whenever a comet approaches the Sun the outer crust of its nucleus is heated—to a depth of a few metres—and it is gases from this outer crust that form the envelope and tail of the comet. As the comet draws away from the Sun, gases from the interior of the nucleus rise to the surface and fill the spaces in the outer crust. The quantity of gas in the nucleus decreases with every revolution of the comet about the Sun.

The comet's tail, therefore, is not eternal. The time will come when it will appear no more.

Astronomers have estimated that Halley's Comet possesses enough gas for another hundred and twenty revolutions about the Sun, that is, for about another nine thousand years. This is a long period because Halley's Comet has a nucleus that is about 20 kilometres in diameter. Comets with a small nucleus expend their gas much more rapidly.

The nucleus of the comet is not long-lived, either.

It sometimes happens that the nucleus immediately splits into two, three or five huge pieces. In such cases the pieces part com-

pany in space and each of them is followed by a tail: in this way several comets are formed from one.

There is an interesting story of what happened to Biela's Comet. This comet made one revolution in almost seven years. It appeared punctually in 1832 and 1839 and astronomers expected it to appear again in 1845. The comet appeared at the appointed time but on December 29 met with a misfortune: before the eyes of the observers it broke into two. One part was much bigger than the other and the comet seemed to have acquired a satellite. The distance between the bigger comet and its satellite increased very rapidly and by February 10 was already more than 200,000 kilometres. Then the comet was lost to sight.


Views of a comet at various distances from the Sun

The astronomers were very interested and impatiently awaited the next appearance of Biela's Comet. It arrived in 1852 but its satellite was by then a million and a half kilometres behind the bigger comet —a distance that is four times greater than the distance from the Earth to the Moon.

The comet could not be found in 1859 and 1866 although a careful search for it was made. It reappeared in 1872 but in a changed form. On the night of November 27, 1872, the Earth passed close to the orbit of Biela's Comet. Thousands of bright stars raced across the sky and were extinguished. Biela's Comet had been turned into a meteor stream, a star shower, and this was all that was left of it.

Since then the Earth has crossed the orbit of Biela's Comet many times and on each occasion the star shower has been observed—the flashes of many tiny meteors burning up in the atmosphere.

It is, therefore, the destiny of any comet, no matter how big and

solid it may seem, to turn into a stream of small stones and dust particles racing through space.

Comets are not long-lived. The life of a comet, compared with that of a planet, passes in a moment. All the comets would have disappeared long since if new ones had not made their appearance. Where do they come from?

It is believed that comets are formed by the bursting of asteroids. After the explosion, if one of the pieces begins to move in a greatly elongated orbit, it may become a comet.

Another theory that has been put forward postulates that the comets are formed on the giant planets Jupiter and Saturn. There may be volcanoes on these huge planets that hurl huge blocks of stone into space, and these stones later become comets. Science has not yet found a sufficiently clear explanation of the origin of comets.

THE EARTH COLLIDES WITH A COMET

You already know that in the olden days comets were regarded as the forerunners of all kinds of calamities. When the real nature of comets was discovered these fears abated but new fears made their appearance: the comets have irregular orbits and race through space in all sorts of different directions. Is it unreasonable to assume that a comet might collide with the Earth? If it did there would be a cosmic catastrophe, the Earth would perish under the blow of the celestial terror, rushing through space with a terrific velocity. You must remember that even a hundred years ago astronomers did not know the real dimensions of a comet and believed them to be very great. It was believed, for example, that Lexell's Comet (appearing in 1770) had a mass of at least a trillion, 1,000,000,000,000,000,000 tons.

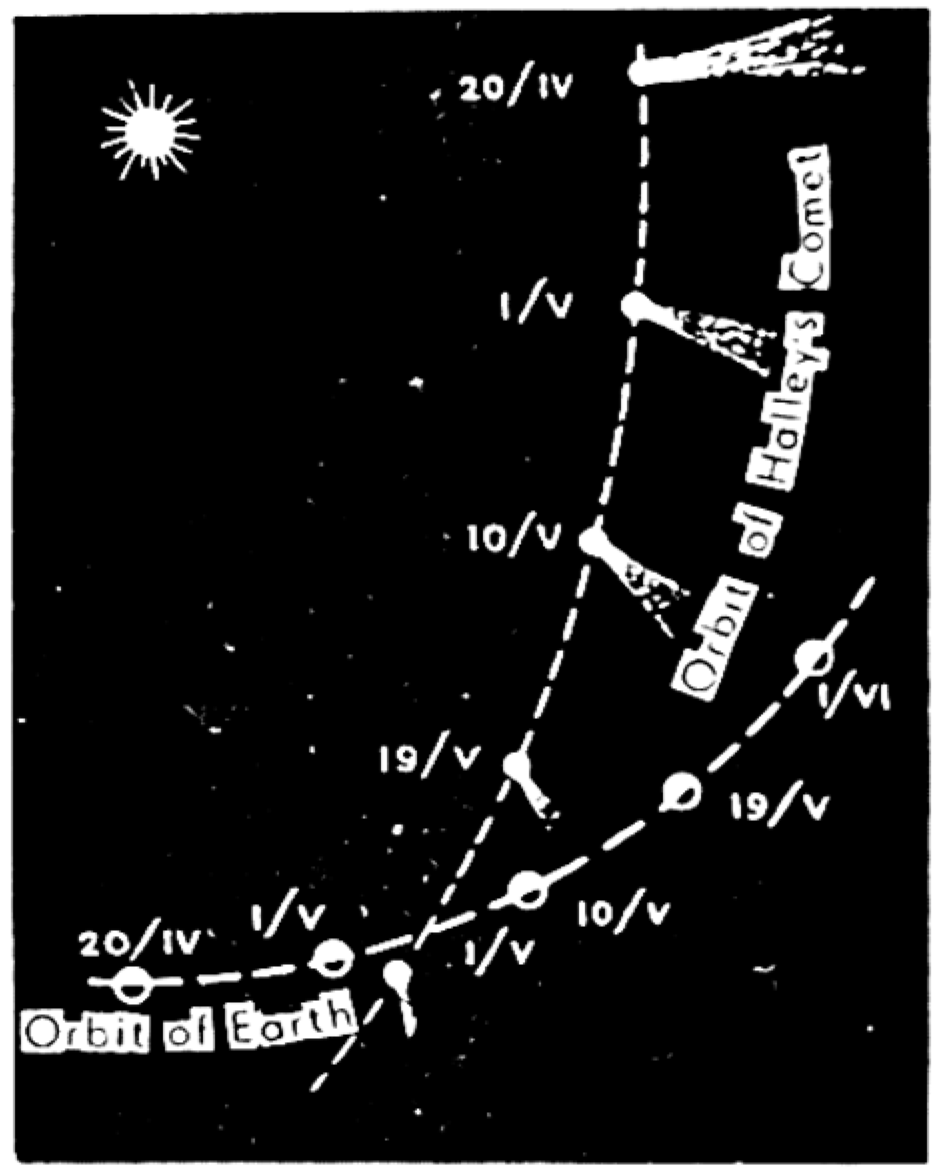
It stands to reason that if such a colossal mass of matter came flying straight at the Earth the consequences would be, to say the least, serious. But when scientists proved that the nucleus of the comet was nothing more than a big stone it became obvious that a collision with it would not constitute a very great danger for the Earth: another big meteorite would fall and that would be all.

Then another great fear arose: the Earth might pass through the comet's tail. People had read in the writings of astronomers that the tail of a comet consists of poisonous gases. The tail of the com-

et, then, would curl round the Earth and suffocate all living things. . . .

There was a much greater chance that the Earth would pass through the tail of the comet than there was of its colliding with the nucleus, since the tails of comets are tens and hundreds of millions of kilometres long and of tremendous width.

Astronomers calculated that in 1910 the Earth actually would pass through the tail of Halley's Comet. Newspapers outdid each other in their stories of the danger that threatened the Earth: the end of the world is at hand, they declared.



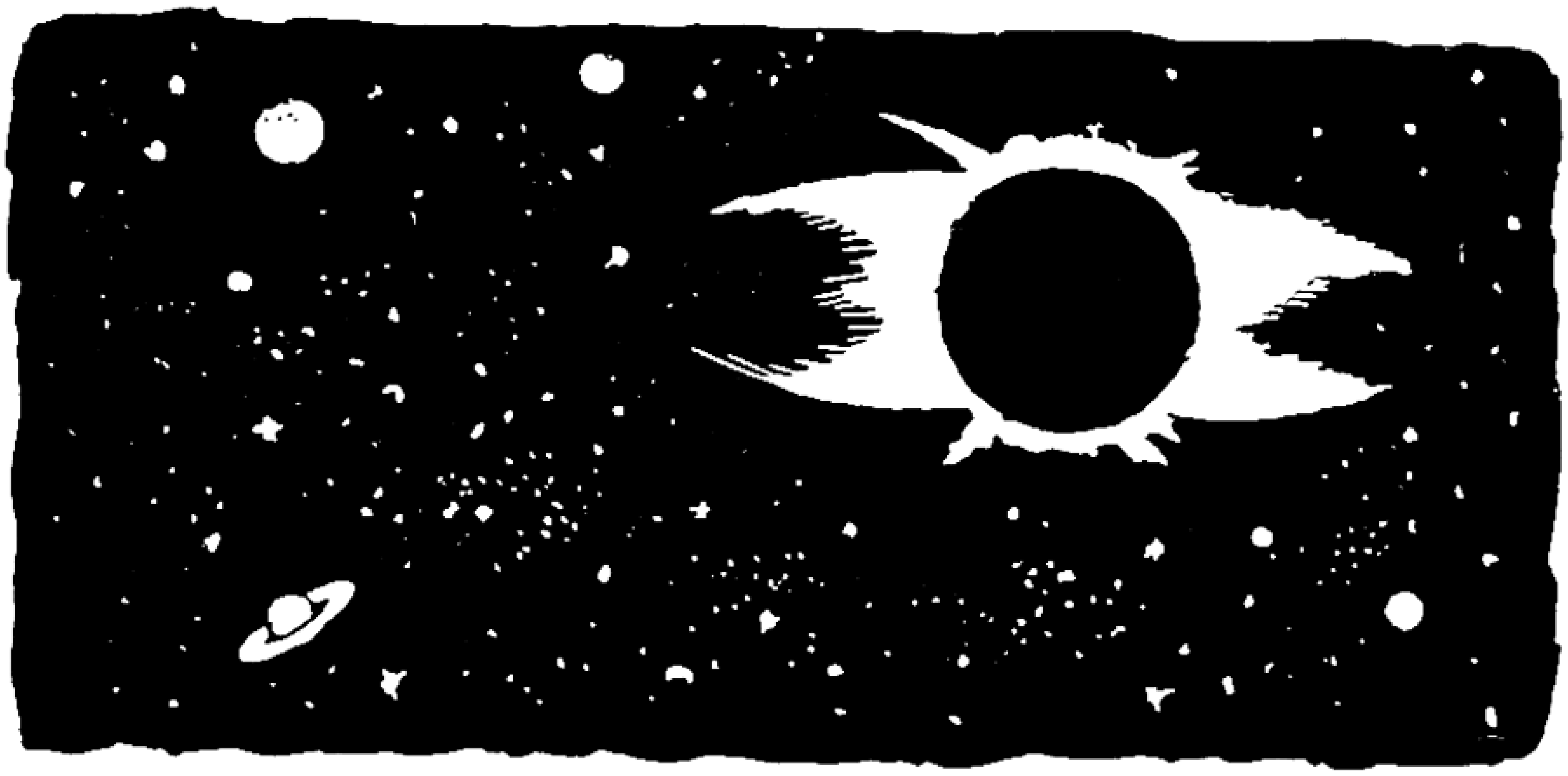
Halley's comet crossing Earth's orbit

As was to be expected the newspapers put fear into the hearts of millions of people. Many people dug gas shelters for themselves (and this was before poison gas had ever been used in warfare). Priests had their hands full hearing the confessions of the large number of penitents. In many places fear drove some people to suicide.

On May 19, 1910, the Earth passed through the tail of Halley's Comet. And what happened? At night the stars shone as brightly as usual, in the morning the birds sang, people still breathed freely. . . .

This is to be explained by the fact that the Earth's atmosphere is several thousand million times denser than the gases that form the comet's tail. It is no easier for comet gases to penetrate the Earth's atmosphere than it is for a mosquito to bite through a steel wall a metre thick. Those who knew this slept as soundly as ever on the night when the Earth passed through the comet's tail.

Thus science is dispelling the fears and superstitions of the people.



PART THREE

THE SUN

Even in very ancient days people realized that without the Sun there could be no life on Earth. They believed the Sun to be a kind and benevolent god. The ancient Greeks called the sun-god Helios, the Romans called him Phoebus (or Apollo) and the Slavs called him Yarila.

According to an old folk saying, on the shortest day in the year in the northern hemisphere, December 22, "the Sun turns towards summer." On this day the Sun seems to be born again after having gradually died away during the previous six months. The Sun finally overcomes the evil forces of winter on the day of the spring equinox.

In olden days the people celebrated the birth of the Sun in winter; and in spring they celebrated the resurrection of nature that had been frozen during the winter. These pagan festivals have remained to the present day as Christmas (the birth of Christ) and Easter (the resurrection of Christ).

The Sun is the mighty source of all life on Earth. Without the light and warmth of the Sun not one living thing—from man down to the tiniest bacillus—could live. The heat of the Sun is the source of all activity, or, more scientifically, of all energy on Earth except atomic energy.

Until very recently every machine in the world delivering energy obtained it from the Sun. But in 1954 the first atomic power station in the world went into operation in the Soviet Union. This power station is worked by the energy that is confined in certain forms of matter.

In one of the fairy tales by the great Russian poet, Alexander Pushkin, Prince Yelisei addressed the following words to the wind:

Strong and mighty, Wind, art thou,
Thou dost pile up cloud on cloud,
Thou dost set the sea a-seething,
Over all thy blast a-breathing,
There is none that thou dost fear....

For hundreds of millions of years the winds blew freely over the Earth and, although they had no master, they performed a tremendous amount of useful work.

Tiny drops of water, a countless number of them, hang in the air, and are turned into steam by the heat of the Sun. In the form of light vapour they rise higher and higher until they reach those layers of the atmosphere in which it is always cold. The dispersed, invisible vapour condenses and once more turns into drops of water. If these tiny drops had remained on the Earth's surface we should have called them mist but high up in the atmosphere they form clouds.

Now try to imagine that some great evil force were to make the air immovable, that there were no more wild hurricanes raging over land and sea, no more moderate winds that are so often mentioned in weather forecasts and not even any more light and pleasant breezes.

What would happen? The clouds would hang motionless in the air throughout their allotted span of life, until the tiny drops of water merged into big drops too heavy to float in the atmosphere and would then fall back into the ocean from which they came without performing any useful work. And this would keep happening over and over again.... The great circulation of water would cease, the rivers and streams would dry up, the green grass in the meadows, the corn in the fields and the trees in the forests would become scorched and yellow.... All dry land would become a desert. The plains would be covered with a thick layer of dust until

they resembled those lunar seas that we explored after our imaginary flight on an interplanetary rocket.

This is not the only service performed by the wind—that of bringing rain to the thirsty earth and making streams that run together to form mighty rivers. Our weather to a very great extent depends on the direction of the wind.

Winter. The frost outside is —40° C. A weather forecast broadcast over the radio says: "Masses of cold air are moving from the arctic towards the Northern and Central Regions of European Russia causing a considerable drop in temperature which will last for several days. . . ."

What are these "masses of cold air from the arctic"? They make up the cold wind that comes to us from the icy wastes of the arctic.

The opposite also happens: in the middle of winter a warm wind comes to us from the south, there are running streams in the streets, the ice of the skating rinks melts—the warm wind brings us a short-lived spring.

This exchange of air masses between the different parts of the Earth is a great thing. It makes the climate more bearable, it brings cool weather to hot places and warms up cold areas by bringing warm air.

Apart from these big jobs the wind has a lot more work to do for the benefit of man. People make the wind work for them—it drives ships, turns the sails of wind-mills and the vanes of wind-motors. This last-named job is one that is gaining more and more importance every year. In the treeless regions, where there are strong winds all the year round, wind-motors are an economical source of power to drive electric generators: the power they generate is stored in accumulators and can be used as needed.

And so, the wind is our benefactor, although we sometimes take offence at its practical jokes. If the wind blows off your hat or your cap or breaks a window-pane by slamming the window—these are mere trifles that are not worth talking about. But there are more serious things—hurricanes that tear the roofs off houses, tear up trees by the roots, sweep trains off the rails, sink ships at sea. . . . Nevertheless, we must forgive the wind for the calamities it brings because of the immeasurable benefits we reap from it.

We have already said that there would be no rivers without the wind, and running water is itself a tremendous source of power. In

days of old people used only a tiny fraction of this power by building water-mills on small rivers or floating rafts on them, but today man has learned to make the rivers do real work. Mighty rivers are dammed and the impounded water falls from a height on to the blades of a turbine coupled to an electric generator. Electric power is sent out along wires to all parts of the country to perform all kinds of work that formerly could not even be dreamed of.

For a long time now people have been accustomed to the idea that electricity makes machines work, lights up our homes and the streets of our cities. But who would have thought, even fifty years ago, that electricity would plough up the soil, cut down trees and uproot stumps in the forests, chop feed for the cattle and even milk the cows.

Some of the biggest hydroelectric power stations in the world have been built in the Soviet Union. Two of them, the Stalingrad and the Lenin Volga Station at Kuibyshev each day produce as much energy as could be provided by 75,000,000 men working eight hours a day without the aid of machines. Still bigger stations are being built on the Rivers Angara and Yenisei.

All this energy we owe to the Sun.

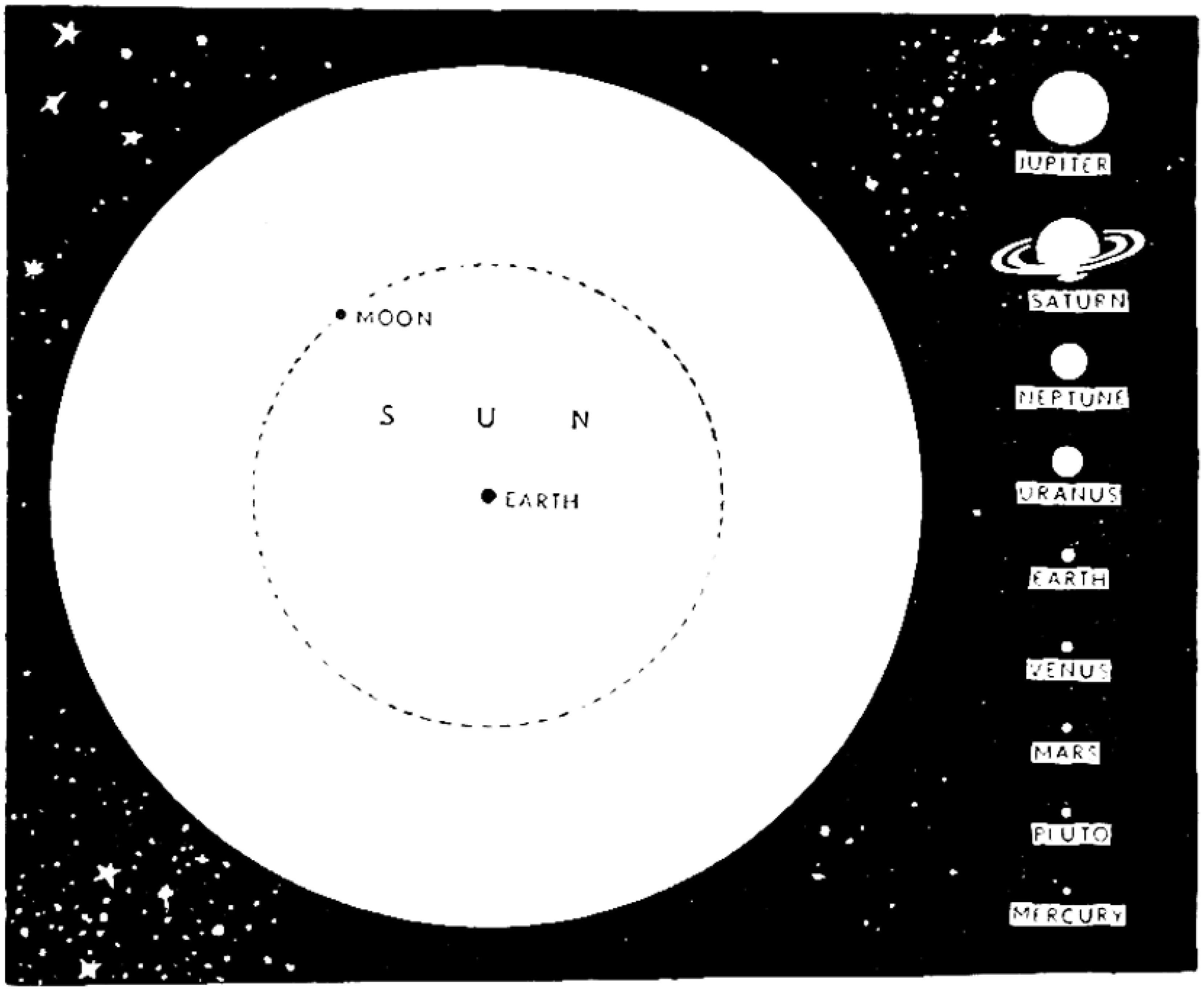
You are having your lunch—meat and vegetables, bread and butter and some fruit. The Sun's rays helped the plants make use of carbonic acid, nitrogen and water to produce the nutritive stuffs we find in cabbage, potatoes, bread, apples or in a piece of watermelon....

Plants cannot live without sunlight and warmth and if there were no vegetation on Earth there would not be any animals or people.

Plants also provide us with firewood, peat and coal. When we burn these things we release from them the Sun's energy that has been accumulated and preserved in the plants for years, for thousands and millions of years.

If the Sun were suddenly to become extinguished people would be able to live for a few years or a few dozen years on the energy accumulated in plant life. After that life on our planet would die out.

The Sun, however, has existed for millions and billions of years and will continue to exist for billions more. In the whole solar system the Sun is the most powerful and most indestructible machine for the production of energy.



If the Sun were a hollow sphere with the Earth at its centre, the orbit of the Moon would fall within the Sun

The Earth receives only one two-thousand-millionth part of the warmth emanating from the Sun. Yet even this is a great deal. The amount of heat received by the Earth each year would be sufficient to melt a sheet of ice 67 metres thick if the Sun's rays fell on it vertically.

It is a good thing for us that we receive such a small portion of the Sun's energy. If all the heat radiated by the Sun reached the Earth at one time our globe would soon turn into a cloud of vapour.

Scientists study the surface of the Sun through telescopes. But how can one look at the Sun through a telescope when it is impossible even to glance at it with the naked eye? Astronomers have found an easy solution to this problem: they cover the telescope lens with a sheet of dark glass that absorbs a great part of the Sun's rays and they can then look at the Sun without any ill effects.

If we look at the Sun through a telescope with a magnification of 100 diameters it looks the same as it would to the naked eye seen at a distance of 1,500,000 kilometres.

Here we have to say something about the limits of the telescope. A telescope cannot cover the whole disc of the Sun at once and only a small part of it is in the field of vision. If you have ever used opera-glasses in a theatre this effect will be familiar to you. If you look at the stage with the unaided eye you see the whole of it, but if you use your opera glasses to get a better view of the expression on the face of one of the actors, you see him alone, for only his face is within the field of vision of your glasses. If you want to look at the other actors you have to turn your glasses on each of them in turn.

This is a disadvantage common to all kinds of telescopes and binoculars. It cannot be cured and so it has to be endured.

The Sun is an enormous luminary. If you take a tiny pea to represent the Earth you will need a very big water-melon to represent the Sun. The Sun's diameter is 109 times that of the Earth. The diameter of the Earth is a little over 12,000 kilometres, so that of the Sun will be almost 1,400,000 kilometres.

Imagine that the Sun is a hollow sphere with the Earth at its centre. There would be room inside that sphere for the Moon as well which could revolve round the Earth at its normal distance of 384,000 kilometres and from its orbit to the Sun's surface there would still be 300,000 kilometres.

The volume of the Sun is 1,300,000 times that of the Earth: this means that you could make 1,300,000 balls the size of the Earth out of the Sun. Nevertheless, the Sun is only 330,000 times heavier than the Earth because the density of the material from which it is made is only a quarter of the density of the Earth. This can easily be understood when we remember that the Sun is a body with such a high temperature that the material of which it is made up can only exist in the form of vapours and gases.

The temperature at the surface of the Sun is $+6{,}000^\circ$ C. The hardest materials on Earth melt at temperatures between $+3{,}000^\circ$ and $+4{,}000^\circ$ C. Tungsten, the metal of which electric light filaments are made, melts at $+3{,}400^\circ$ C. On the Sun's surface the most refractory materials are turned into vapour.

Although the surface of the Sun is very hot, its interior is much

hotter. According to the computations of astronomers the internal temperature of the Sun is something monstrous— $+20,000,000^{\circ}$ C! We can only guess what matter is like at such temperatures.

Imagine that a tiny particle of solar matter heated to a temperature of $+20,000,000^{\circ}$ C. were to fall on Earth and to shine with its unbearable luminosity. This one tiny particle would burn up everything all round for hundreds of kilometres.

SUN SPOTS

In times past people used to think that the Sun was the most perfect celestial luminary that could possibly exist.

"The Sun has no deficiencies," said the scientists.

And then ... how disappointed they were. Galileo pointed his telescope at the Sun (he smoked the lens before he did so) and saw dark patches on it that had been invisible to the naked eye. When he announced his discovery he was not at first believed.

It is said that Galileo visited another scientist, one who stuck to old, accepted views, and told him about the Sun spots.

The scientist shook his head and answered with a professorial air:

"Brother, I have read and re-read the ancient books many times and I can assure you that nothing is said in them concerning the spots of which you speak. Go in peace and remember that these spots exist only in your own eyes!"

Later, however, everybody had to admit that there are spots on the Sun. Since then, in order to justify the shortcomings of some famous man, people say:

"Why, even the Sun has spots on it!"

Sun spots and protuberances

We still do not know exactly what these spots are: some scientists believe that they are enormous gas vortices that form on the surface of the Sun, but their origin is still unknown.

The spots have lower temperatures than the space surrounding them and are, therefore, darker in appearance. It should not be thought that one could take shelter from the Sun's heat in these spots. It has been determined that the temperature of the spots is $+4{,}800^\circ$ C. which is only $+1{,}200^\circ$ C. cooler than the surrounding space. The spots are dark by contrast only. If you strike a match in a dark room its light is blindingly bright. But if you hold a lighted match in front of a bright electric lamp its flame will look dark to you. The same is true of the Sun spots.

Northern Lights seen from an arctic station

The spots are of a tremendous size, some of them being hundreds of thousands of kilometres in length and breadth. If a solid sphere the size of the Earth were thrown into one of these spots it would disappear like a cork thrown into a bonfire.

Some of the Sun spots disappear shortly after their appearance while others last several weeks and even months. During their observations of the long-lasting spots, astronomers have made some interesting discoveries. It has been shown that the Sun, as Giordano Bruno predicted, rotates around its axis. This means that the Sun has poles and an equator. It must not be thought, however, that the solar poles are any colder than its equator.

The Sun does not rotate about its axis in the same way as the Earth does. The Sun is a gaseous ball and various parts of it rotate at different velocities. The rotation is fastest at the equator and

slows down towards the poles. The equatorial region of the Sun makes one revolution about the solar axis in 25 terrestrial days but closer to the poles a revolution takes 30 days.

Long observation of the Sun spots showed astronomers that their number keeps changing, increasing and decreasing. It has also been discovered that the spots are periodic with a period of about eleven years.

You have heard about the Northern Lights, of course, and, if you live in the north, you will have seen them with your own eyes. For a long time scientists could not explain the nature of the Northern Lights.

Lomonosov wrote: "It is most likely that the Northern Lights are due to electric forces operating in the air."

It has been shown that the Northern Lights are more frequent and brighter in those years when there are the most Sun spots. The Sun spots throw out gigantic streams of electrically charged particles into space. Some of these particles reach the Earth and collide with particles of air in the upper layers of the atmosphere and the air becomes luminous.

Magnetic storms on Earth also result from these mighty streams of electricity coming from the Sun. Magnetic storms are not at all like ordinary storms. The sky may be perfectly cloudless, there may not be a breath of wind in the air, the birds may be singing merrily.... But a compass needle will swing from side to side unable to rest in its proper position with one end pointing to the north and the other to the south.

If you go into the forest on a dull day and take a compass with you so as not to lose your way, a magnetic storm may cause you some trouble.

When there are strong magnetic storms short-wave radio stops working all over the world. This is not a minor trouble, it is a very serious one. The first Soviet arctic drifting station, North Pole 1, could communicate with the mainland only by short-wave radio. It sometimes happened that radio communication stopped for two or three days at a time; this was the fault of a big group of Sun spots that on those days was passing across that side of the solar disc facing the Earth.

It has also been discovered that Sun spots affect our terrestrial weather. The more spots there are on the Sun the more storms

there are on Earth. It is believed that the periodicity of wet and dry years is also connected with the periodicity of the Sun spots. This is a very complicated problem and it has not yet been fully studied.

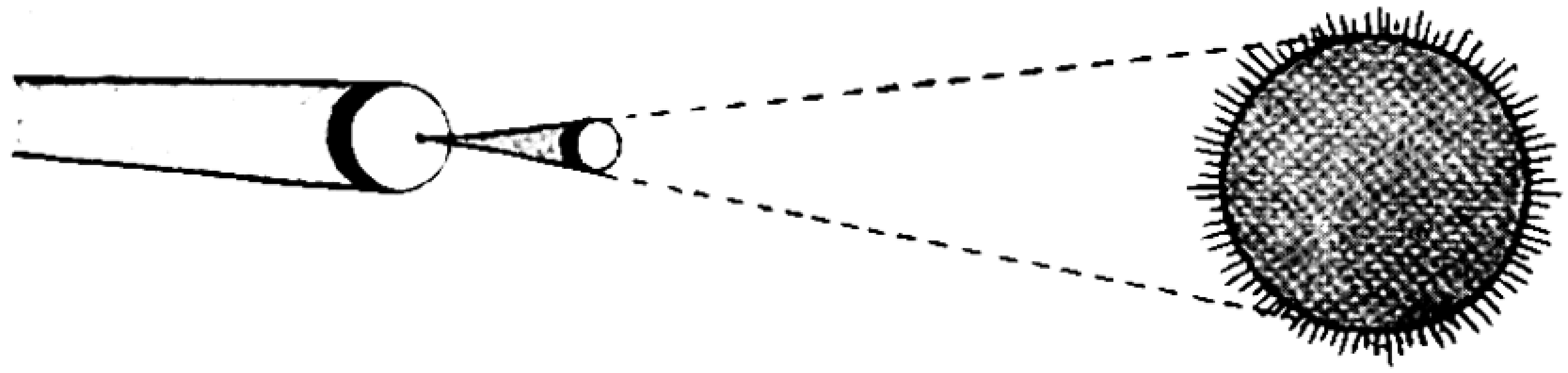
ECLIPSES OF THE SUN

In times long past solar eclipses frightened the people much more than lunar eclipses: the people understood that they would perish if the Sun disappeared from the sky for ever.

The Sun was believed to be a benevolent god who gave life to all creatures on Earth. And suddenly, on a perfectly cloudless day, a black, evil-looking shadow would begin to move across the Sun. It would spread and spread ... it covered half the disc ... the Sun was reduced to a crescent ... then it disappeared!

Terror seized the people. "The last day of the world has come,

Total solar eclipse



How a solar eclipse occurs

the Universe is perishing," they thought. The life-giving Sun had disappeared. . . . It must have been destroyed by hostile forces. . . .

And then the people were overcome with the greatest joy as the edge of the Sun began to glow again after a few minutes' darkness. Half an hour later the whole sky had regained its usual magnificence.

Even in the animal kingdom there is excitement and consternation during a solar eclipse. Cows moo, sheep bleat and the dogs whine plaintively. . . . The night birds set out in search of prey and the day birds go to their nests to sleep.

Solar eclipses, like those of the Moon, may be partial and total. A partial eclipse does not make such a great impression on the people—sunlight merely loses some of its strength.

In the chapter on "Lunar Eclipses" we said that even in ancient days astronomers learned to forecast them. They were not, however, always successful. There was an interesting case in China about four thousand years ago. There was a solar eclipse and the court astronomers, Hi and Ho, had not warned the people and the emperor.

An old Chinese chronicle describes this as follows:

"The astronomers Hi and Ho have forgotten all virtue, they have given themselves up to excessive drunkenness, abandoned their duty and are not worthy of their high titles. They are the first to neglect the annual computation of the heavenly luminaries. In the last month of autumn, on the first day of the month, the Sun and the Moon met despite all expectations. The blind were informed of it by the beating of a drum, thrifty people were filled with consternation and the simple people fled. Hi and Ho occupied their high posts but heard nothing and knew nothing."

For neglecting their duty or perhaps because of a simple mistake

in their calculations, Hi and Ho paid with their lives—they were beheaded by order of the emperor.

There is a great difference between solar and lunar eclipses. A lunar eclipse can be observed in any part of the world in which the Moon is visible at the time because the Earth's shadow completely covers the Moon. A solar eclipse takes place when the Moon is between the Earth and the Sun; the Moon's shadow falls on the Earth and, since all three bodies are moving in space, the Moon's shadow runs across the surface of the Earth at great speed. The solar eclipse, therefore, can only be seen in those places where the narrow strip of the Moon's shadow falls.

Now you will want to know how the little Moon can cover over the huge Sun that is tens of millions times its size. It is all a matter of distance—you can cover over the Sun with a small coin if you hold it close enough to your eyes.

The diameter of the Sun is four hundred times greater than that of the Moon but the Moon is four hundred times nearer to us than the Sun. That is why the Sun and the Moon seem to us to be about the same size—sometimes the Sun looks bigger and sometimes the Moon does.

When the centres of the Earth, the Moon and the Sun are in one straight line there is a total eclipse of the Sun if the Moon at that time looks bigger than the Sun. And if the Moon looks smaller there is an interesting and very rare phenomenon; this is known as an annular eclipse of the Sun when the Moon covers the centre of the Sun but there is a bright ring all round it.

If the Moon passes to one side of the straight line between the centres of the Earth and the Sun the eclipse is partial and not total.

An astronomer living in a town which he never left would have to wait a long time to see a solar eclipse. Total solar eclipses rarely occur twice in the same place.

A total eclipse of the Sun was visible in the U.S.S.R. on June 19, 1936. It crossed the whole territory of the Soviet Union, from the Pacific Ocean to the Black Sea, in a strip 200 kilometres wide. The shadow of the Moon during an eclipse moves at a speed of 60 kilometres a minute, or a kilometre a second. This is two or three times as fast as the fastest passenger planes. Aircraft fast enough to enable people to overtake the shadow of the Moon during an eclipse have only recently been constructed. The astronomers work differently:

they take up their stations at a large number of points on the Earth through which the shadow will pass; the eclipse of 1936 was observed by twenty-eight Soviet and a number of foreign stations.

The next eclipse visible from the territory of the Soviet Union occurred on September 21, 1941, when the shadow of the Moon crossed the territory of the Central Asian Republics.

On June 21, 1945, an eclipse should have been visible from the northern regions of the U.S.S.R. but observation was hindered by cloudy weather, the astronomer's biggest enemy.

The last eclipse visible in the U.S.S.R. occurred on June 30, 1954, when the total phase lasted two minutes.

During a total solar eclipse it is possible to observe some very interesting phenomena that cannot be seen at other times.

THE SUN'S CORONA

There was once a time when the Sun was called the King of Planets. Kings wear crowns and the Sun, too, has its crown or corona.

Astronomers first discovered this corona during total eclipses. It is a radiant glow that extends beyond the solar surface for hundreds of thousands of kilometres. The corona gives off much less light than the Sun—actually it possesses only about half the luminosity of the Moon. That is why it is not visible around the Sun which is thousands and thousands of times brighter; it only becomes visible when the Sun's disc is covered by the Moon.

The corona is the upper layer of the solar atmosphere. Before the invention of photography astronomers drew pictures of the solar corona but today it is photographed. A total eclipse lasts from two to eight minutes so that it is difficult to make even one drawing in that time; dozens and even hundreds of photographs can, however, be taken.

Apart from the corona, observers have seen prominences at the edge of the Sun's disc during eclipses. Some of them are like clouds and others resemble fountains. These prominences are called protuberances. Some of them really are clouds, clouds of fire that float in the solar atmosphere. They are of tremendous size and last several hours and even several days.

Other protuberances are colossal tongues and fountains of incandescent matter hurled out by the Sun to a distance of hundreds of thousands of kilometres. In 1938 astronomers saw a protuberance a million and a half kilometres high.

Part of the Sun's corona

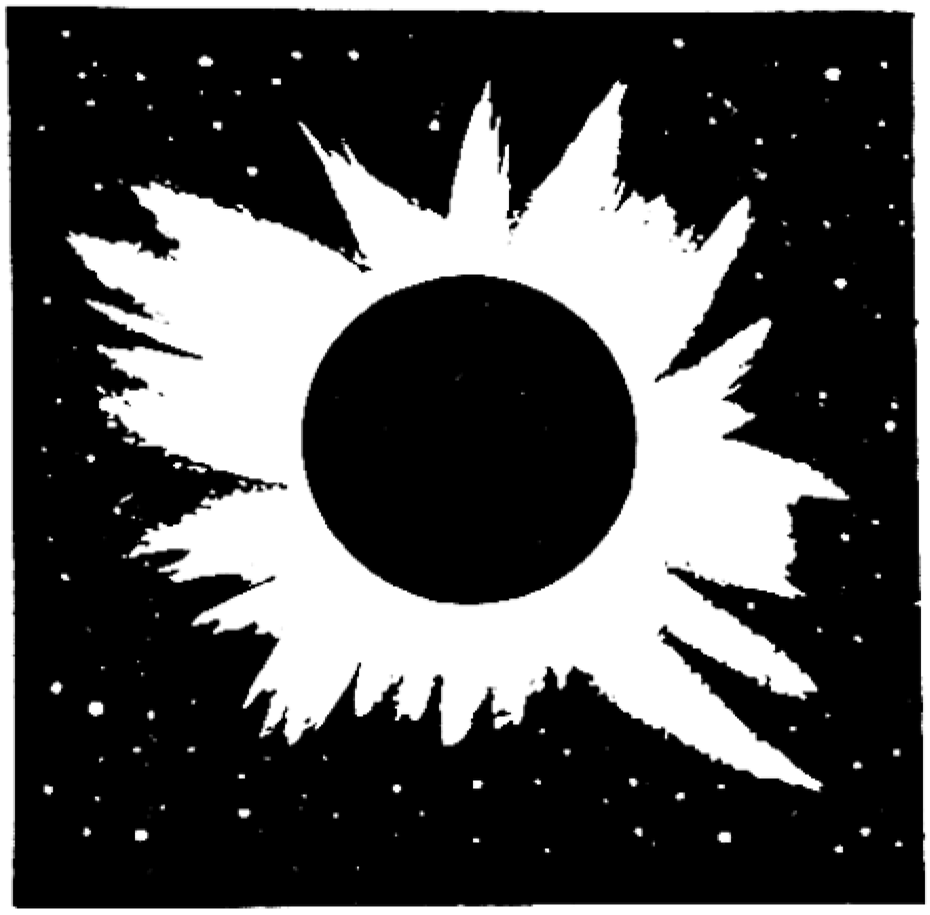
A very great deal has been learned about the Sun since the telescope was invented. The Sun was formerly believed to be a gleaming sphere, something like a huge iron ball that had been heated white hot. No body can remain solid at very high temperatures. The Sun is gaseous and even gas cannot remain motionless at temperatures that reach thousands, tens and hundreds of thousands of degrees. The gas is in constant motion and the force of this motion is much greater than that of the strongest wind on Earth.

The Sun has been in existence for thousands of millions of years and not for one moment of that long period has it been motionless. The storms that rage incessantly in the Sun are of such terrible force that compared to them the worst terrestrial hurricane is like the breath of a new-born babe.

Gigantic Sun spots are formed that hurl tremendous streams of electric energy out into space; there are terrific explosions that cause thousands of millions of tons of incandescent gas to fly through space at the rate of 400 kilometres a second. In the course of ten minutes tongues of fire rise to a height equal to the distance from the Earth to the Moon; if the Moon were to come into the path of

one of these protuberances, its entire surface would be enveloped in fire in a few seconds.

Scientists have learned to make observations of solar protuberances at times when there is no eclipse. Special telescopes have been invented for this purpose and astronomers are able to make constant observations, record the number of the protuberances, photograph them and even make cinema films of them. Each exposure of the film is made separately, at fairly long intervals—every hour for example; if the film is then run off at the normal speed we get a picture of the "life" of a protuberance.



The Sun's corona during an eclipse

Astronomers have discovered that there are most protuberances on the Sun in those years when there are most Sun spots and that they usually make their appearance in the vicinity of the spots. In general, calm years on the Sun alternate with stormy years in which explosions and eruptions are particularly powerful. The calm and stormy years of the Sun's activity make up a cycle or period of eleven years.

The drawing on page 168 shows you the Sun surrounded by protuberances. They have a temperature of about +5,000°C. and are darker than the Sun itself; that is why we cannot see them at ordinary times. If we could see them the Sun would appear to us as a hairy ball with huge bulges on its surface that are constantly changing shape before our eyes.

Scientific investigation has proved that during the last thousand million years the temperature of the Sun has not changed, it has remained constantly at the same high level. And we may say with certainty that the Sun will not cool down for many thousands of millions of years to come.

HOW FAR AWAY ARE THE STARS?

Now let us leave our solar city and make an imaginary journey to the distant parts of the Universe.

In this book I have already told you that in ancient days the people regarded the stars as fixed. Actually the whole Universe revolves around the Earth, although, of course, you now know that this revolution is only an illusion. The distance from one star to another is always the same.

Take the constellation we know as the Great Bear, for example. Two thousand years ago the stars were in the same relative position as they are today and will remain that way for thousands of years to come.

But this immobility of the stars is also an illusion: they are racing through space at a terrific speed, but they are so far away from us that we cannot detect their motion.

For several centuries scientists tried to estimate the distance from the Earth to the stars but they were unable to do so. In 1837, the astronomer V. Y. Struve, the Director of Pulkovo Observatory, succeeded in measuring the distance to the star Vega. He found that Vega is about 1,700,000 times farther away from us than our own Sun!

The important thing was to take the first step. In Struve's time and after him other astronomers computed the distance to many of the stars.

The nearest star to us was given the name of Proxima which means "nearest" in Latin. Proxima is not a very big star, it can only be seen through a good telescope from the Southern Hemisphere. Astronomers call it Proxima Centauri because it is in the Centaurus constellation.

Let us calculate how much time it would take to reach Proxima. What transport shall we use? Let us imagine that a fantastic railway has been built as far as Proxima and that the first train is standing in the terrestrial station awaiting the signal to leave. You and I run, panting, to the booking office.

"Are there any tickets left for Proxima?"

"Yes," answers the booking clerk, calmly.

"How much for two tickets?"

"Let me see," answers the clerk, "since it is a long journey the

railway company has fixed a very reasonable rate—one ruble per million kilometres."

"Why, that's cheap enough!" we exclaim, very pleased with ourselves.

"Wait a bit," says the booking clerk. "One ruble per million kilometres makes a hundred and fifty rubles for an astronomic unit. To Proxima it is two hundred and sixty thousand units—that'll be thirty-nine million rubles each, please."

We step back from the booking office window in fright.

"And . . . and . . . how long will the journey take?"

"I can reckon that out, too. We are sending an express, a hundred kilometres an hour. The journey to the Sun takes a hundred and seventy-three years and to Proxima it is twenty-six thousand times farther. . . . You'll reach your destination in about forty-five million years!"

"Are there any stations on the way?"

"I don't think so, unless some asteroid wanders across the line."

We back away from that booking office:

"We'll look in another day, when we're not so busy."

The booking-clerk looks sadly at us as we walk away:

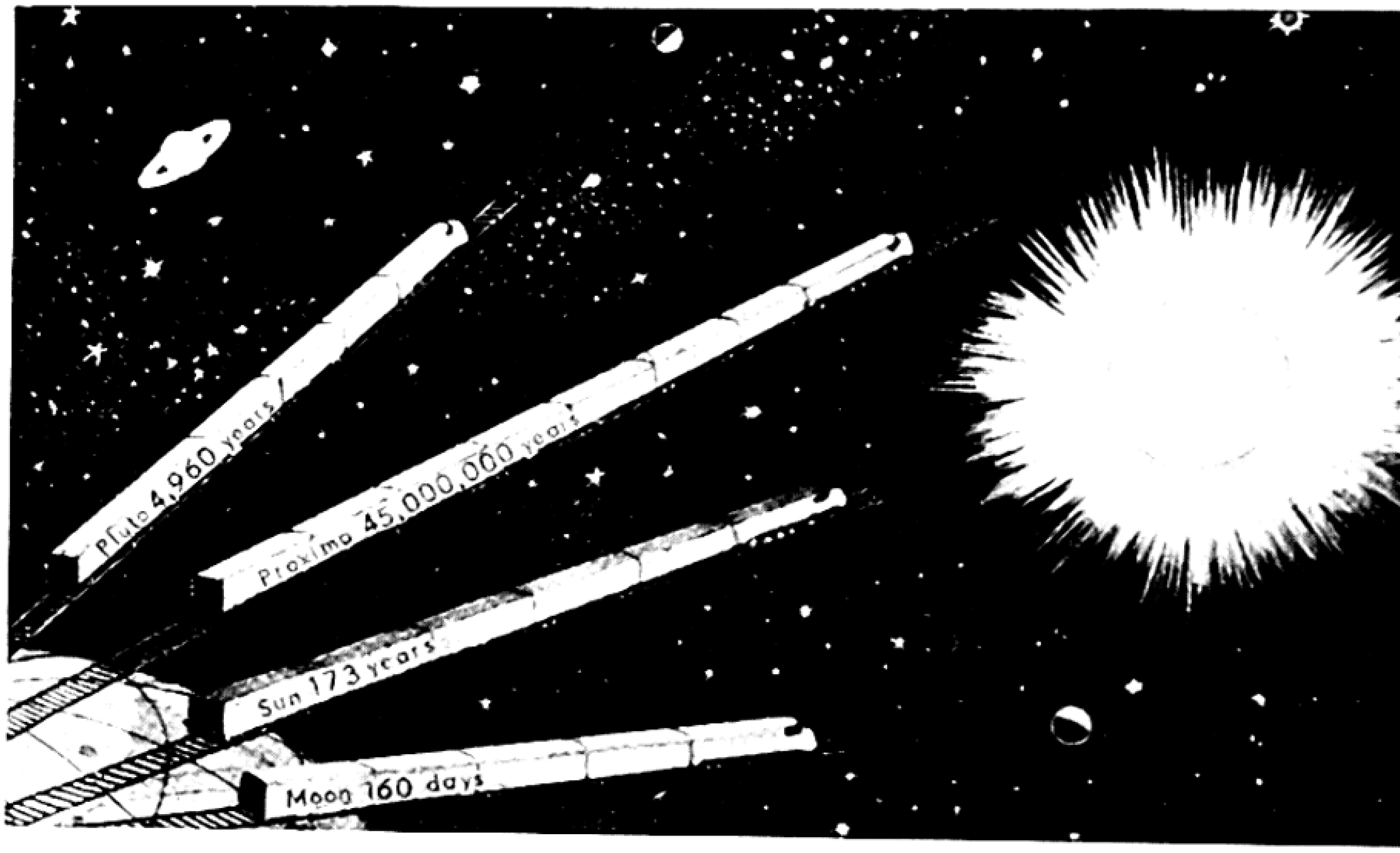
"It looks as though the train will never start, all the passengers are running away. . . ."

And so we see that a railway train is useless for interstellar travel. Then we remember the rocket. Our imaginary journey to the Moon took about 36 hours and the highest velocity attained by the rocket was 11.2 kilometres a second, or about 40,000 kilometres an hour.

Now we'll try and calculate how much better it would be for us to go to Proxima on a rocket. The rocket travels 400 times faster than a train, so that the number of years required for the journey will be 400 times less. We divide forty-five million by 400 and. . . . Even a rocket would take 112,000 years to reach the nearest star. You see from this how far away the stars are!

We have already mentioned in this book that the fastest thing in the world is a ray of light. It covers a distance of 300,000 kilometres every second—that is almost the distance from the Earth to the Moon. If only we could travel on a beam of light!

A ray of light travels one astronomic unit, the distance from the Earth to the Sun, in 8 minutes 20 seconds. There are 1,440 seconds



Imaginary trains leaving Earth for a journey into space

in a day, that is 173 times 8 minutes 20 seconds. We could, therefore, travel about 173 astronomic units a day on a beam of light and in a year we could travel 63,500 astronomic units or 63,500 times the distance from the Earth to the Sun.

Astronomers call the distance travelled by a ray of light in one year "a light year" and this is the unit used to measure distances in space.

The astronomic unit was very convenient for the measurement of distances inside the solar system, but when we have to measure distances to the stars, it is much too small. Even to Proxima the distance is 260,000 astronomic units and there are stars thousands and even millions of times farther away. To measure the distance to such stars in astronomic units would be the same as measuring the distance from Moscow to Vladivostok in millimetres.

So remember: the year is a unit of time, three hundred and sixty five and a quarter days; a light year is a unit of distance, 63,500 astronomic units.

How many light years is it to Proxima? One light year equals 63,500 astronomic units; the distance to Proxima is 260,000 astronomic units; the answer, therefore, is more than four light years.

Here is another imaginary scene.

An expedition sent out from the Earth to Proxima reached its destination safely. The space travellers had taken a very powerful radio station with them and soon got into touch with the Earth.

"Hallo, hallo. This is Proxima. Proxima calling. Do you hear me, Earth?"

"Hallo, Proxima. Hallo, Proxima. Earth calling Proxima. Reception is good. How was your journey?"

"We had an excellent journey, no adventures worth mentioning. We are expecting you to send us more people and provisions."

"Didn't you find any inhabited planets there?"

"We haven't found one yet. We are camped on a small planet but it is a wilderness and the food is not suited to terrestrial stomachs."

"All right. We'll send out spaceships with passengers and goods. Earth is now closing down. Good-bye, Proxima."

"Good-bye, Earth."

How long do you think this terse conversation would take? Well, over twenty-five years! After each question the stations would have to wait over eight years for the answer because radio waves travel with the speed of light. Even at its terrific velocity of 300,000 kilometres a second it takes light waves more than four years to reach the Earth from Proxima. And there are other stars that are immeasurably farther away.

How immense is the Universe! It is almost impossible to imagine just how far away from us the nearest stars are. Perhaps the story of the train, the rocket and the radio conversation will help you.

And how small the people of ancient days imagined the Universe to be!

There is one ancient Greek legend which says that the god Hephaestus (the Roman Vulcan) dropped an anvil from the sky on to the Earth and that it flew through the air nine days and nine nights. The Greeks thought that such a distance was exceedingly great although a falling object would only travel 580,000 kilometres, a little more than the distance to the Moon, in nine days and nights.

Even our solar system is thousands of times bigger than the Greeks imagined the whole Universe to be.

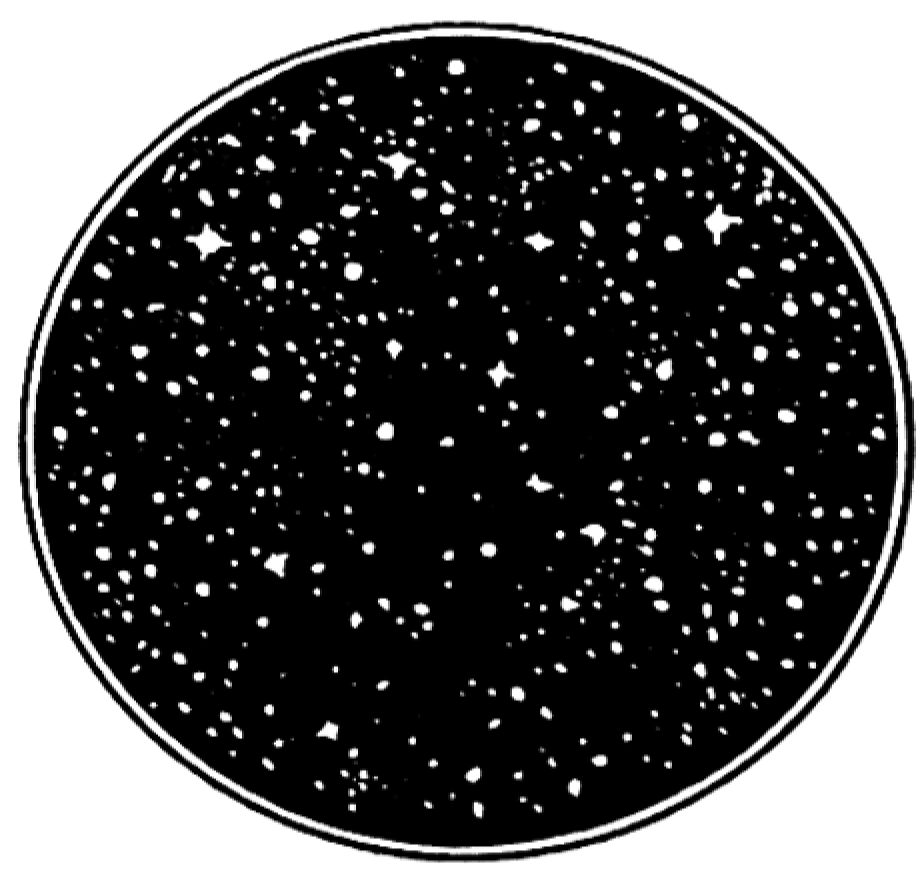
A PICTURE OF THE STARRY SKY

The starry sky on a moonless night makes a wonderful picture. Stars, big and little, twinkle brightly against a background of dark blue sky; it seems that there must be millions of them. As you gaze up at the sky you imagine that it would be impossible to count them. This is not so, for all the stars visible to the naked eye on one hemisphere were counted long, long ago, and there are only about three thousand of them.

Yes, only three thousand instead of that unbelievable multitude that staggers the imagination. . . .

The first catalogue of stars was compiled in the 4th century B.C. by the Chinese astronomer Shi Sheng. A star catalogue is a list of all the stars with their exact places in the sky properly marked.

Later and quite independently of Shi Sheng the Greek astronomer Hipparchus also compiled a catalogue. He did not catalogue all the stars but only the thousand brightest. His contemporaries called the work of Hipparchus a great feat as, indeed, it was. In those days it was extremely difficult to determine the position of a star in the sky; the astronomer had only the very simplest instruments and made his observations with the unaided eye.



Part of the sky seen through a telescope

Later, in the 15th century, an excellent star catalogue was compiled by order of the Khan of Samarkand, Ulugh Beg. More than a hundred scientists worked in the observatory built by Ulugh Beg, and the remains of it are still to be seen in Samarkand today.

Although the Samarkand observations were made without the aid of a telescope they were extremely accurate. For the first time in sixteen hundred years after the death of Hipparchus the position of the brightest stars in the sky was determined. Later all the stars visible to the naked eye were entered in the catalogue.

The stars visible to us without a telescope are but a tiny fraction of the number visible with one. When Galileo pointed his weak little telescope at a part of the sky where three stars were visible to the naked eye he saw there twenty stars. As telescopes became better, more and more stars were discovered. Millions of stars can be seen through the most powerful modern telescopes but, naturally, not all of them are entered in the catalogue. Nevertheless, there are hundreds of thousands of stars in the present-day catalogue.

Even the stars that are not included in the catalogue are all carefully recorded by astronomers. The whole sky is divided up into regions, each of which is allotted to a definite observatory. The astronomers of each observatory photograph their own region in accordance with certain rules and always on photographic plates of the same size. If there is reason to believe that a new star has appeared or an old one disappeared in a certain region of the sky the astronomers merely have to photograph the region a second time and compare the new negative with the old.

It is time for us to speak about the great importance of photography in the study of the stars.

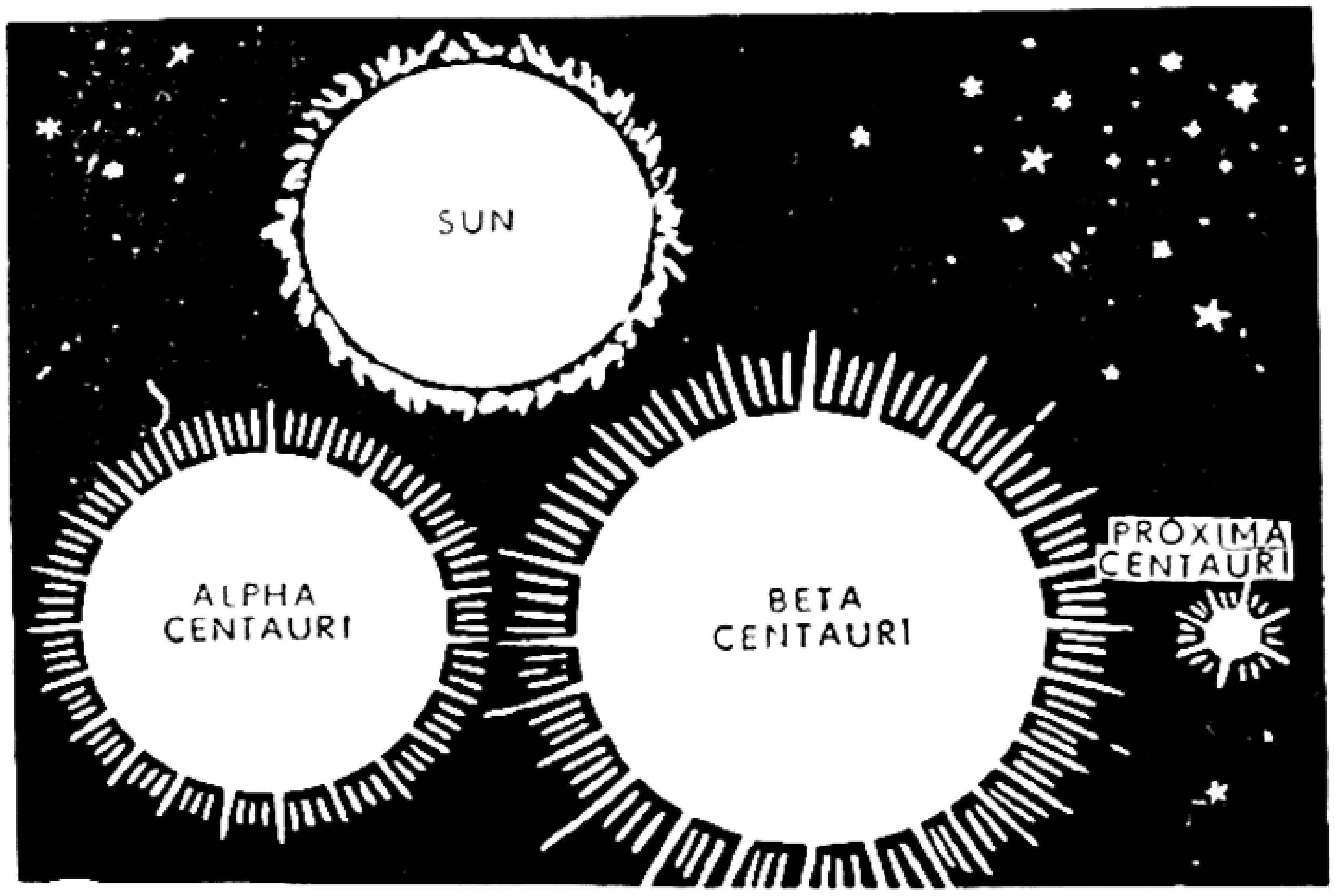
In ancient times a terrible form of torture was used: water was allowed to drip on to a man's hand, drop by drop. At first sight this does not seem like torture: the first drops do not harm the hand, then the skin forms a blister, it bursts and every further drop falling on to the wound causes unbearable pain. The saying: "Dripping water wears away a stone," is a very old one.

Light rays act on a photographic plate or film in the same way. At first the light rays from a very weak star do not affect the plate; but time passes, minute after minute, hour after hour, and the image of the star appears on the plate. The ray, in a way, carves on the plate an image of the star that sent it out. But the human eye is not so sensitive: if an observer did not see a weak star the first time he looked in that direction through a telescope he will never see it at all even if he continues staring at it for ten hours on end.

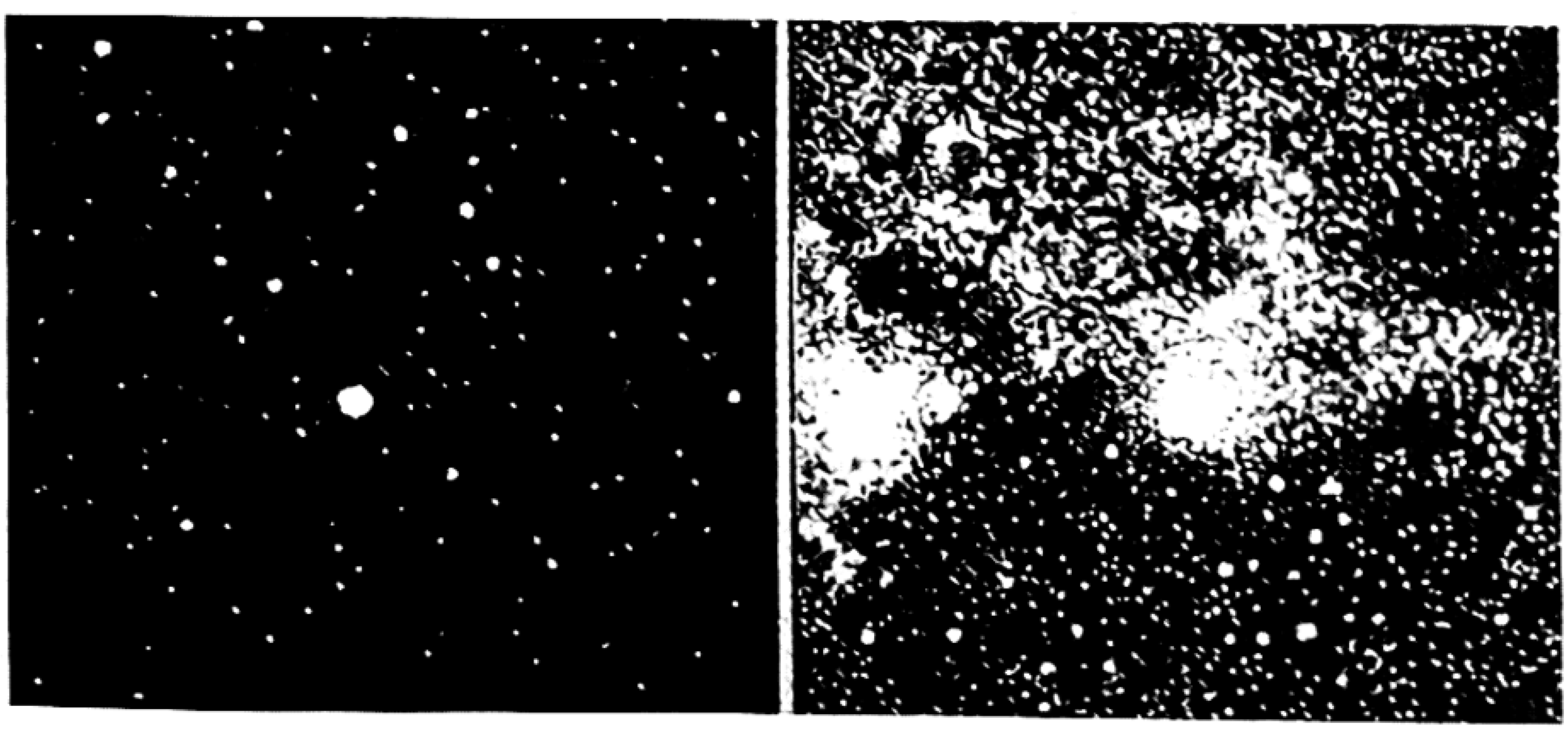
Look at the pictures on p. 183.

The left-hand one is a photograph of a region of the sky around the star Alpha Cygni as we see it; the right-hand photograph is the same region taken with an exposure of thirteen hours.

In order to get an image of the star in the form of a tiny spot of



The comparative sizes of the Sun and some stars



Part of the sky seen (left) with the naked eye and (right) as photographed through a powerful telescope

light and not a line on the photographic plate, the telescope has to be turned by clockwork, keeping all the stars in the field of vision in one place on the plate.

A catalogue of the stars not only gives their position in the sky but also their luminosity or degree of brightness. The stars are also classified according to their brightness—some are very bright, others extremely weak.

The full Moon gives 3,000 times more light than the whole skyful of visible stars. If we were to have one small Moon more, even a hundredth part of the real Moon, it would shine more brightly than all the stars put together.

Seen through a telescope, the stars are like tiny bright dots against a dark-blue background. The telescope does not magnify a star or show it to us as a disc or circle like a planet. It only brings it closer to us, but it is still too distant for us to see it as a circle. Because of this, because the telescope brings the stars nearer to us, we can see those that are invisible to the naked eye. The telescope does not increase the size of individual stars but increases the number of visible stars and their brightness.

Stars are of different colours. Sirius is white, Capella is yellow, Arcturus is orange and Aldebaran is red. The names of these stars are very old, but they are still in use. It stands to reason, however, that not every one of the stars now known has its own name, only the brightest being named.

From the earliest times people noticed that some of the brightest stars are placed close together and form figures in the sky. These figures are called constellations. We said something about the constellations of the Northern and Southern Hemispheres in the chapter called "Points of the Compass."

Astronomers still call constellations by the names the Greeks gave them. In later times, however, astronomers discovered many new constellations in the sky and gave them names; the new names are usually those of simple things and are not taken from mythology. In this way there appeared in the sky a Clock, a Microscope and even a Pump and Compasses, although astronomers call them by their Latin names, such as Horlogium, Microscopium, etc.

In the sky today we recognize eighty-eight constellations. What use are these constellations to astronomers? They realize that a constellation is only a group of visibly bright stars. In this book we have

said several times that the stars are only apparently fixed or motionless. They are actually moving at great speed but are very far away; only in the course of hundreds and thousands of years is it possible to notice that some star or another has moved to a different place. The constellations change their shape constantly but unnoticeably.

We give names to the constellations for the same reason that we give names to streets and squares in a city or village. It is very easy to give the "address" of a star by its constellation. We have said that very few stars have their own names: the others are named as follows. Every constellation consists of several bright and many weaker stars. The bright stars are given letters of the Greek alphabet, such as α Centauri ("alpha" of the Centaurus constellation), β Hercules, etc. The weaker stars are given numbers such as 61 Cygni (the 61st star in the Cygnus constellation).

The chief constellations of the northern sky

Mariners, travellers on land, aviators, geologists and many others have to be able to recognize the more important constellations. They help them find their way by night in unfamiliar places.

You will also find it useful to learn the names and shapes of the chief constellations: when you are older you may have to find your way by the stars.

There is one thing about a map of the sky that we often forget. The picture we see is not a true representation of the Universe as it really exists. Every star is a sun and by means of its light it tells us of its existence. Light, however, is not transmitted instantaneously but at a speed of 300,000 kilometres a second. This seems a tremendous speed to us earth-dwellers, but we already know that light takes over four years to reach us from the nearest star. There are stars that are so far away that their light takes thousands and millions of years to reach us.

We do not see a star as it is today but as it was in the past. Try to imagine the impossible: all the stars in the sky are extinguished simultaneously. Would the sky be black and dark immediately? Not at all. The first star would go out four years later, that would be Proxima; it would disappear for the astronomers with their telescopes, but with the naked eye we should not notice it as we cannot see it anyway. The other stars would continue to shine as usual and in three or four years two or three other small stars would disappear. Brilliant, gleaming Sirius would go out nine years after the catastrophe but this would still make little difference to the picture of the sky as we see it. Hundreds and thousands of years would pass and the starry sky would still continue to spread over the Earth and only after many millions of years would the astronomer with a powerful telescope (if there were still people on the Earth by then) see the last star disappear from the sky.

Take another case. An astronomer has seen a star suddenly flash up in the sky (this does happen—the new stars are called novae). When did it first burn up so brightly? Today. Certainly not today, but perhaps a hundred or a thousand years ago although its light rays have only today brought us news of this event in the Universe. A star that first burns up brightly today will be seen by astronomers on Earth hundreds and thousands of years from now.

The light rays from the star are the only information we receive from distant worlds. Do they tell us much? Do they merely inform us that somewhere in space there is a star? No, for people have invented such clever instruments that they can gain a lot of information from a beam of starlight: they know how far distant the star is, in which direction in space it is moving and at what speed and also of what substances it is made. Scientists sometimes find out the age of a star, its volume and mass and even (although so far in only a few cases) whether it rotates about its axis and whether it has satellites (planets).

Astronomy has reached a high level of development. If the astronomers of old could have been told how much their descendents would learn about the stars they would no doubt have said:

"That's all fantasy!"

That which was impossible yesterday has become possible today, for the human mind is constantly penetrating deeper and deeper into the secrets of the Universe.

AFTERWORD

The era of space travel dates from the launching of the first Soviet artificial earth satellite on October 4, 1957. This was followed by the first artificial planet of the solar system, then a Soviet pennant was landed on the Moon and a little later the far side of the Moon was photographed by a Soviet space vehicle and the photos transmitted back to Earth.

In 1960 another step forward in the Soviet conquest of space was made when living beings—dogs and other animals—went out into space and returned safely to Earth.

On February 12, 1961, when this book was being printed, Soviet engineers and scientists sent an automatic interplanetary station towards the planet Venus, opening up man's path into the distant regions of outer space.

This space laboratory, unlike the previous ones, was not sent out directly from the Earth's surface. A heavy Earth satellite, driven by a huge multi-stage rocket, was first put into orbit about the Earth and on that same day, in response to a radio signal from Earth, another rocket carrying the automatic station left the space vehicle and set off in the direction of Venus. This automatic station is a gigantic affair weighing 643.5 kilograms; it is equipped with radio instruments capable of sending and receiving messages over millions of kilometres and contains a large number of measuring instruments to investigate conditions in outer space.

The whole world was amazed at this wonderful achievement! The instruments carried by the interplanetary station had to be very precise and yet they also had to be strong enough to withstand the terrific jolt given them when the rocket first put the Earth satellite into orbit and a second jolt when the automatic station was rocketed from the spaceship towards Venus. And these delicate instruments, a tangle of fine wires, levers, switches, relays, etc., had to be so designed that not a screw would be loosened or a spring weakened by these two gigantic jolts. Nevertheless, everything worked perfectly, and the first reports radioed back to Earth showed that the station was racing along its long road to Venus. It should reach its goal in the second half of May 1961.

Only a month had elapsed after the cosmic station set out for Venus when the world was again amazed by news of another Soviet space

achievement. This great event was the first manned space flight.

On April 12, 1961, at seven minutes past nine (Moscow time), the spaceship *Vostok*, carrying a pilot, Major Yuri Gagarin of the Soviet Air Force, was put into orbit around the Earth. The *Vostok* weighed 4,725 kilograms. The ship carried out a research programme in the course of a full orbit round the Earth and at fifty-five minutes past ten landed safely in the Soviet Union in the pre-arranged area.

All through the flight, the courageous space pilot kept in touch with the Earth by wireless. A radiotelemetric and a TV systems informed observers on Earth of the pilot's condition during the flight. Both during the flight and when landing Yuri Gagarin felt fine.

The flight of the *Vostok* with a gallant pilot on board was a great victory over the forces of nature. Soviet science and engineering had scored a great triumph. The heroic flight opened up a new era in world history.

Only four years lay between the launching of the first artificial Earth satellite and the flight of the *Vostok*. You have read in this book about the different sputniks and spaceships that were sent up during those four years. The Soviet Union fired the first intercontinental ballistic missile, sent the first spaceship towards the Moon, built the first solar satellite and sent a spaceship towards Venus. One after another Soviet spaceships carried living creatures into space and brought them back to Earth. It was naturally in the order of things that a Soviet man should be the first to make a space flight; his great exploit that will live for all time embodies the genius of the Soviet people and the might of socialism. The space age has been opened!

Before very long automatic stations will land on the Moon, Venus and Mars and will send back to Earth radio reports of their observations and photographs of those heavenly bodies; robots will prepare landing places for spaceships and then man will be able to set foot on new worlds.

TO THE READER

The Foreign Languages Publishing House would be glad to have your opinion regarding this book, its translation, design and printing, and to receive any suggestions from you.

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